Experimental and Research Station,

Nursery & Market Garden Industries' - - Development Society, Limited, - -

Turner's Hill, Cheshunt, Herts.

Sixth Annual Report,

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Experimental and Research Station.

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Tomato Grower..... A. E. Judd.

Gardener ..... A. J. Grundy.

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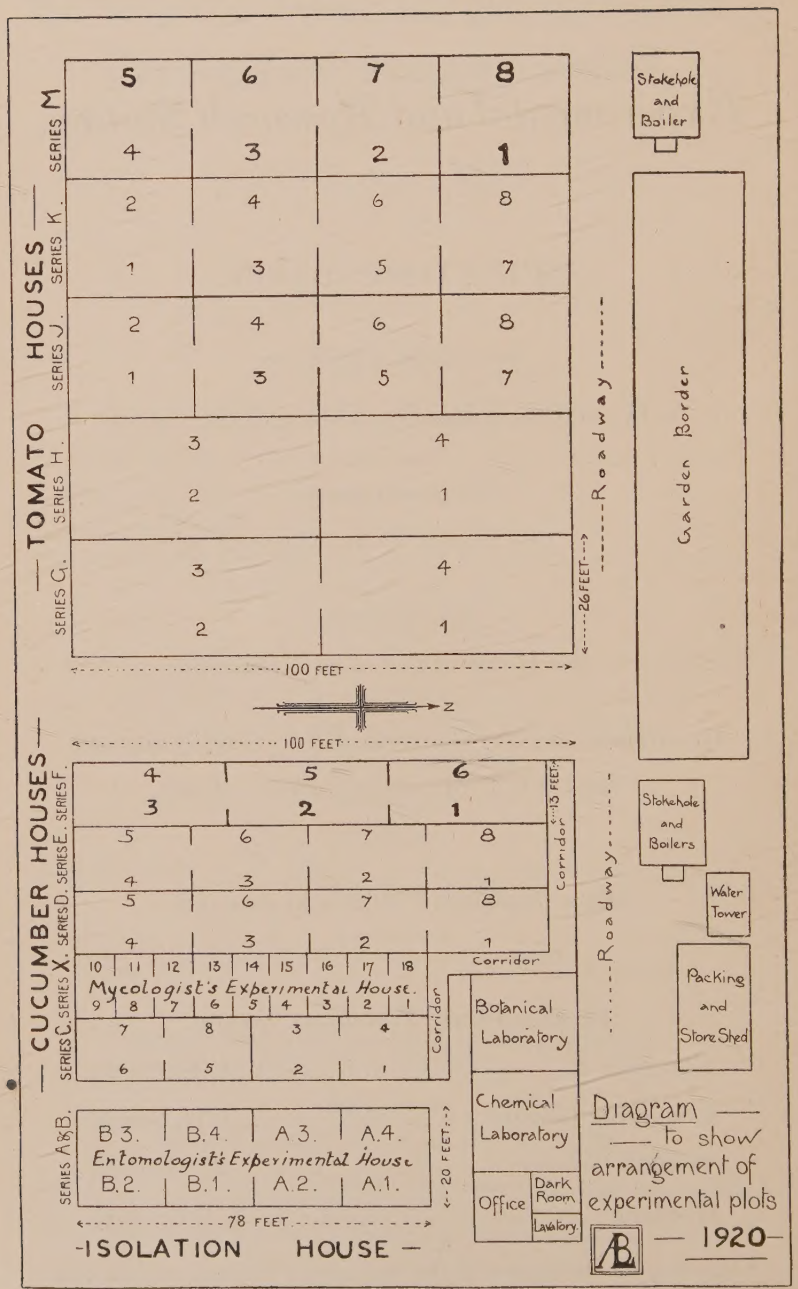

— TOMATO HOUSES —
SERIES M.
SERIES K.
SERIES J.
SERIES H.
SERIES G.
5 6 7 8
4 3 2 1
2 4 6 8
1 3 5 7
2 4 6 8
1 3 5 7
3 4
2 1
3 4
2 1
100 FEET
26 FEET
Roadway
Garden Border
Stokehole and Boiler
Z
100 FEET
— CUCUMBER HOUSES —
SERIES C. SERIES X. SERIES D. SERIES E. SERIES F.
4 5 6
3 2 1
5 6 7 8
4 3 2 1
5 6 7 8
4 3 2 1
15 FEET
Corridor
10 11 12 13 14 15 16 17 18
9 8 7 6 5 4 3 2 1
Mycologist's Experimental House.
Corridor
7 8 3 4
6 5 2 1
Corridor
Botanical Laboratory
Chemical Laboratory
Office
Dark Room
Lavatory
Roadway
Stokehole and Boilers
Water Tower
Packing and Store Shed
SERIES A & B.
B 3. B.4. A 3. A.4.
Entomologist's Experimental House
B.2. B.1. A.2. A.1.
20 FEET
78 FEET
— ISOLATION HOUSE —
Diagram
— To show arrangement of experimental plots
— 1920 —

General Report.

THE Nursery and Market Garden Industries' Development Society, Ltd., continues to make steady progress in its many activities throughout Great Britain and Ireland. It is a pleasure to record that the income from Annual Subscriptions in 1920 was more than double that received in 1919; special efforts are being made to wipe off the deficit on the Capital Account before the end of 1921 and also to put the Station on a satisfactory financial basis for the future. During the year 1920 the Advisory Officer made 737 scientific and technical reports, 514 being sent to growers in the Lea Valley district, and 223 to growers in other parts of the United Kingdom. At the request of members and in connection with the systematic visitation of nurseries or the outbreak of diseases, the Advisory Officer paid 511 visits to nurseries, only 51 of which were outside the Lea Valley district, to investigate and report on matters coming within the scope of the work of the Station.

From the beginning of 1921 the following arrangements as to the division of the work of the Station and its allied organisations have been made to the mutual satisfaction of the Committee of Management and the Members of the Staff. Mr. W. F. Bewley will be responsible for the experimental work on tomatoes and for the mycological research. Dr. Lloyd will be

responsible for the experimental work on cucumbers and the entomological research. Mr. A. B. Lister will be responsible for the outside relationships of the Station in general, the secretarial work and advisory work and the general management of the Society, the Lea Valley Growers' Association, Limited, and Nursery Trades, Limited.

The number of visits from growers (or their representatives) and other interested persons during the year amounted to 1,719.

The experimental work has been, to a great extent, a continuation of that undertaken in the previous year. The experiment in slow versus forced growth in tomatoes was transferred from the divided Isolation House to two of the large houses this year, and the experiment on the relation between the growth of tomatoes and their position in the experimental houses was replaced by a "mulching" experiment.

Some of the experiments having been continued over a period of years, and the Station now being six years old a summary of the completed experiments is given this year as an extension of the summaries given in the Fourth Annual Report.

Obituary.

IT is with deep regret that we record the death, in December, 1920, of Mr. Spencer Percival Umfreville Pickering, M.A., F.R.S., who had been a Member of the Committee of Management since the foundation of the Station in 1914. A chemist of international repute, Mr. Pickering made discoveries, particularly on combinations of copper, which will be of permanent value to science. For a quarter of a century he was associated with the Duke of Bedford in running a scientific fruit farm at Woburn, obtaining important results which were reported in an exhaustive series of annual reports.

The death of Mr. William Bince Randall in March, 1921, removed from our midst one of the most active members of the Committee of Management on which he had served for nearly five years. Mr. Randall was one of the leading nurserymen of the Lea Valley, and took a very prominent part in the establishment and development of the Research Station. His boundless enthusiasm and genial personality will be sorely missed by all connected with the Lea Valley Nursery Industry.

RESULTS OF 1920.

Experiments in the Cultivation and Management of Tomatoes.

(a) Slow versus Forced Growth.

The results of the previous three years justified the continuance of this experiment on a large scale for another year and it was transferred to houses 1 and 2 where the conditions approximated to those of a trade nursery.

The earliest and most valuable yield is shown, as before, by the forced section of all the four varieties. The result of this experiment as regards total yield is the opposite to that of last year, for whereas in 1919 the initial superiority of the yield from the forced section was confined to the month of June, in 1920 it was maintained to the end of August, and finished with a total gain of 8 per cent. over the slow section, as against a loss of 8 per cent. in 1919. In this respect it was similar to the total yield of 1918. See Table I.

(b) Mulching Experiment.

This season marked the commencement of an experiment to determine the effect of mulching upon crop yield and the incidence of disease.

House 5 was divided into eight equal plots, two of which received no mulch, two were mulched with clean straw, and four were mulched with dung in the usual manner: apart from these treatments the plots were uniformly cultivated. The results obtained by examining the average yield in tons per acre, show the greatest yield from the unmulched plots, the next from the straw mulched plots, and the lowest from the dung mulched plots. The straw mulched plots showed the cleanest growth of all the plots and the least "stripe" disease. In 1921 the experiments are to be carried out on a larger scale under normal nursery conditions. See Table II.

Table I.

Crops in lbs. per plant grown in borders (50 ft. by 13 ft.) containing 250 plants and occupying 5/336ths of a house acre.

VARIETY.	Series G. Forced Growth.								Series H. Slow Growth.							
	May.	June.	July.	August.	Sept.	Oct.	Total. lbs. per plant.	Total. Tons per acre.	May.	June.	July.	August.	Sept.	Oct.	Total. lbs. per plant.	Total. Tons per acre.
"Comet"	0.07	2.25	1.28	1.22	0.72	0.51	6.05	44.4	0.04	1.72	1.46	0.75	0.82	0.65	5.44	40.8
"Fillbasket"	0.05	1.68	1.62	1.22	0.37	0.34	5.28	39.6	0.01	1.02	1.24	0.79	0.64	0.37	4.07	30.5
"Ailsa Craig"	0.08	1.70	1.39	1.08	0.47	0.46	5.18	38.9	0.02	1.45	1.43	0.94	1.12	0.58	5.54	41.6
"Kondine Red" ... ...:	0.17	2.08	1.48	0.92	0.74	0.35	5.74	43.1	0.02	1.41	1.70	0.75	1.03	0.48	5.39	40.4
Relative Values	411	138	99	137	64	80	109	—	100	100	100	100	100	100	100	—
Tons per acre	0.69	14.4	10.8	8.27	4.27	3.07	—	41.5	0.18	10.5	10.9	6.05	6.77	3.90	—	38.3

Table II.

Treatment and Plot Number.	House No. 5. Series M.								
	Lbs. per plant.						Total.		Average.
	May.	June.	July.	Aug.	Sept.	Oct.	Lbs. per plant.	Tons pr acre.	Tons pr acre.
1 Dung Mulch ...	0.17	1.81	0.94	0.75	1.07	0.43	5.17	38.8	39.9
3 „ „ ...	0.10	1.75	0.94	0.71	1.02	0.48	5.00	37.5	
5 „ „ ...	0.06	1.55	1.23	1.19	1.13	0.43	5.59	41.9	
7 „ „ ...	0.06	1.72	1.25	0.95	1.16	0.39	5.53	41.5	
2 No Mulch ...	0.14	2.03	0.94	0.69	0.97	0.39	5.17	48.8	42.5
6 „ „ ...	0.08	1.54	1.05	0.89	0.92	0.36	4.84	36.3	
4 Straw Mulch ...	0.08	1.64	1.06	0.92	1.14	0.62	5.46	41.0	40.5
8 „ „ ...	0.08	1.58	1.10	0.90	1.20	0.48	5.34	40.0	

The Manurial Experiments.

(a) Tomatoes.

The increase in crop through the omission of nitrogen in Plot 7 and the diminution where nitrogen in any form has been added, has in previous years been the most striking feature of these experiments. Similar results, however, have not been obtained this year. With the variety "Comet" complete artificials with added dung, and standard treatment plus complete artificials, have given the highest yields and are followed by complete artificials without nitrogen. In the case of "Kondine Red" complete artificials with added dung gave the highest yield, followed by complete artificials, while the untreated control plot, complete artificials without nitrogen and standard with complete artificials came next with equal yields. Results of this nature had been expected sooner or later, for the continued cultivation of plants upon land to which no nitrogen is given must necessarily lead to such a diminution of that nutrient as seriously to reduce the crop. The relatively high yield from these plots where dung has been given may be partially explained by the extra heat which is imparted to the soil by the dung. In a cool summer like that of 1920 that factor must be of considerable importance. As before the omission of potash has seriously depressed the crop, bringing it down by $3\frac{3}{4}$ tons per acre in the case of "Comet" and by 5 tons in the case of "Kondine Red." This supports the conclusion drawn from other experiments that on our soil potash is a highly important fertiliser for tomatoes.

Table III.

Plot Number and Treatment.	Series J. Variety "Comet."								Series K. Variety "Kondine Red."								Mean of two Series.
	Lbs. during					Total.			Lbs. during					Total.			
	June	July	Aug.	Sept.	Oct.	Lbs. per plant.	Tons per acre.	Relative.	June	July	Aug.	Sept.	Oct.	Lbs. per plant.	Tons per acre.	Relative.	
5. Complete artificials	.89	.89	.35	.61	.71	3.45	27.4	100	1.68	1.15	.68	.73	.70	4.94	39.2	100	100
6. Complete artificials less phosphates	.85	.93	.35	.61	.59	3.33	26.4	97	1.50	.98	.58	.49	.85	4.40	34.9	89	83
7. Complete artificials less nitrogen	.91	1.15	.34	.43	.74	3.57	28.3	103	1.95	.76	.77	.45	.52	4.45	35.3	90	97
8. Complete artificials less potash	.78	1.03	.29	.47	.54	3.11	24.7	90	1.63	.93	.47	.45	.81	4.29	34.0	87	89
4. Complete artificials plus dung ...	1.15	.80	.50	.77	.43	3.65	28.9	106	1.41	1.03	.67	.93	.80	4.84	38.4	98	102
3. Standard treatment plus C.A. ...	.96	.82	.51	.79	.59	3.67	29.1	106	1.44	.89	.67	.72	.60	4.32	34.3	87	97
2. Untreated control plot	1.17	.99	.47	.39	.47	3.49	27.7	101	1.36	1.14	.83	.58	.69	4.60	36.5	93	97
1. Double complete artificials ...	.97	.88	.40	.58	.47	3.30	26.2	96	1.05	1.06	.66	.54	.40	3.71	29.4	75	86

(b) Cucumbers.

The experiments in houses D and E were a repetition of those carried out last year in which the effect of the quickly acting artificial manures was tested both in the presence and absence of dung. In these two houses the artificials shown in Table IV. were mixed in the original borders and also in the top dressings. In house F a modification of this experiment was carried out for the first time; no dung was used, the artificials consisting of a mixture of superphosphate, ammonium nitrate and sulphate of potash were added in the top dressings only. This course was followed because in previous years it has been noticed that up to a point the plants grown in loam alone look as well as those grown in loam and dung, and it seemed that a stimulating treatment given at this point might result in a better crop.

As in previous years a contrast may be made of the crops obtained from plants grown in loam only against those grown in loam and dung. In the present case the advantage of dung is slight, being only about 2 per cent. This point is dealt with fully elsewhere in this report and it is shown that the advantage is slight when the Spring is mild but great when the Spring is severe. Also, it is there shown that the effect of the shadow of the laboratory, which cuts off the morning sun from the North end, is so great that the crops of D1 and 8 and of E1 and 8 must not be included in the comparisons. They are placed in Table V. but are enclosed in brackets and they are disregarded in the following account.

Artificials in the Absence of Dung.

The control plot of loam gave 44.8 lbs. per plant. Where complete artificials were added the crop was less, *i.e.*, 43.1 lbs., while in 1919 the crop from this plot equalled its control. Where potash was omitted from the artificials the crop was still less, 41.2 lbs., and if the average of the two years be taken the crop just equals the control. Where superphosphate was omitted the crop was also less, *i.e.*, 42.2 lbs., but on the average of the two years this plot gives a slightly higher yield than its control. Where nitrogen was omitted the crop was greater, *i.e.*, 46.3 lbs., confirming last year's results in which this plot was better than the control by about the same amount. The only point that emerges from this is that the ammonium nitrate may be slightly harmful, but it is wiser to postpone any attempt to draw conclusions until the series has been repeated.

In F., where the complete artificials were added in the top dressings only, the resulting crop of the two plots so treated averaged 39.2 lbs. per plant, slightly less than the crops from

the control plots of loam only which averaged 39.7 lbs. Clearly the treatment did not improve the crop, and the view that the low yields given by loam alone is not due to a lack of readily utilisable food is again confirmed.

Artificials in the Presence of Dung.

The control plot of loam with 33 per cent. dung, E. 5, gave 47.9 lbs. per plant, and the plots containing the artificials all gave lower yields than this, the reverse of what occurred in 1919. The interesting point in the series is that among the four combinations of artificials the combination omitting phosphate gave the lowest yield, 40.3 lbs., and the complete artificials the next lowest, 43.2 lbs. This also occurred in 1919 so it appears to be probable that in the presence of dung additional potash and nitrogen are harmful to the crop, while from the figures the superphosphate may very well be beneficial, its full effect being obscured by the presence of the excess nitrogen or potash.

Table IV.

Showing the quantities of the various artificial manures employed in the manurial experiments with cucumbers.

	Ammonium nitrate.	Sulphate of potash.	Superphosphate.
Houses D. and E., to a 24 foot run of border,			
Original border ...	1½ lbs.	1 lb.	2½ lbs.
First ten top dressings ...	6 oz.	3 oz.	8½ oz.
Second ten top dressings ...	9 oz.	5 oz.	13 oz.
House F., to a 32 foot run of border,			
Twenty top dressings ...	8 oz.	4 oz.	11½ oz.

Table V.

Cucumber Manurial Experiments. 1920.

Showing crops in lbs. per plant and tons per acre obtained by various treatments.

D and E grown in borders (24 ft. by 3 ft.) containing 12 plants, and occupying 1/280th of a house acre. F. grown in borders (32 ft. by 3 ft.) containing 16 plants and occupying 1/210th of a house acre.

Plot No.	Composition of Original border.	Composition of Top dressing.	Lbs. per Plant.	Tons per Acre.	Relative Values
D. (1.	Loam 2 parts, dung 1 part ...	As original border	33.6	50.40)	
5.	" " " " ...	" " "	46.5	69 76	104
2.	Complete artificials, no dung	" " "	43.1	64.62	96
3.	Artificials without nitrogen, no dung	" " "	46.3	69.40	103

Table V. (continued).

Plot	No.	Composition of Original border.	Composition of Top dressing.	Lbs. per Plant.	Tons per Acre.	Relative Values
D.	6.	Artificials without phosphates, no dung	As original border	42.2	63.27	94
	7.	Artificials without potash, no dung	„ „ „	41.2	61.84	92
	4.	Loam only	„ „ „	44.8	67.26	100
	(8.	„ „	„ „ „	35.6	53.43)	
E.	(1.	Loam 2 parts, dung 1 part ...	As original border	38.7	58.03)	
	5.	„ „ „ „ ...	„ „ „	47.9	71.97	107
	2.	Complete artificials, added dung	„ „ „	43.2	64.89	96
	3.	Artificials without nitrogen, added dung	„ „ „	43.7	65.55	97
	6.	Artificials without phosphates, added dung	„ „ „	40.3	60.43	90
	7.	Artificials without potash, added dung	„ „ „	44.6	66.94	99
	4.	Loam only	„ „ „	44.8	67.26	100
	(8.	„ „	„ „ „	33.0	49.56)	
F.	1.	Loam only	As original border	40.0	59.95	100
	5.	„ „	„ „ „	39.4	59.13	
	2.	„ „	Loam and complete artificials	38.7	58.15	98.7
	4.	„ „	Loam and complete artificials	39.6	59.41	
	3.	Loam 2 parts, dung 1 part ...	As original border	43.9	65.94	101
	6.	„ „ „ „ ...	„ „ „	36.5	54.79	

Forced and Slow Growth in Cucumbers.

These experiments have been carried out for two years in succession and last season's results are shown in Table VI. As in 1919 the forced growth produced twice as much fruit up to the beginning of May; the total crop for the year, however, was only 2 per cent. greater than that of the slow growth. In 1919 it was 10 per cent. greater, the forcing having a more pronounced effect in the colder Spring.

The important relation which exists between temperature conditions and the incidence of certain diseases was exemplified in this experiment. Leaf spot of the cucumber caused by *Colletotrichum oligochætum* in each year appeared first in the section apportioned to slow growth. With the approach of Autumn and the consequent lower temperatures it appeared in the other portion also.

Table VI.

Crops in lbs. per plant grown in borders (18 ft. by 3 ft.) containing 9 plants and occupying 1/373rd of a house acre.

Series C. Treatment.	Lbs. per plant.							Total.		Relative.
	Mar.	April.	May.	June.	July.	Aug.	Sept.	Lbs. per plant.	Tons per acre.	
Forced Growth 1	0.71	11.0	15.9	8.15	8.29	7.29	1.41	52.8	79.2	
2	0.88	11.6	15.5	10.0	10.7	8.8	2.3	59.8	89.7	
3	1.02	11.9	12.2	8.66	7.51	4.35	2.62	48.2	72.3	
4	1.29	10.3	9.96	6.39	6.83	4.89	1.24	40.9	61.4	
Average.	.97	11.2	13.4	8.3	8.3	6.3	1.9	50.4		102
Slow Growth 5		6.46	17.8	10.5	9.19	7.33	3.17	54.5	81.8	
6		5.44	14.2	10.5	10.6	7.19	1.34	49.3	74.0	
7		5.69	15.7	9.39	8.54	5.49	3.0	47.8	71.7	
8		8.11	13.7	8.84	7.36	5.58	1.61	45.2	67.8	
Average.		6.4	15.3	9.8	8.9	6.5	2.3	49.2		100

Soil Sterilisation Experiments.

Experiments in trade nurseries were continued in the same houses and on the same plots as in the previous year at both Nurseries, No. 1 and No. 2.

The results are set out in Tables VII. and VIII. and in respect of Nursery No. 1, while it is still evident that sterilising has a beneficial effect, the results are not as high as might be expected, and it is believed that a physical factor is now coming into operation as the soil in these houses requires deep trenching in order to restore its former physical condition.

Table VII.

Soil Sterilisation Experiments. Nursery No. 1.

TREATMENT.	Plot No.	Yield per plant. June.	July.	Aug.	Sept.	Oct.	Total. Lbs. per plant.	Tons per acre.	Relative.	
House A. 1920										
Steam	1	0.86	1.53	0.63	0.53	0.44	3.99	31.9	100	100
Steam	5	0.55	1.54	0.83	0.49	0.66	4.06	32.4	101	
Carbolic	6	0.88	1.74	0.69	0.49	0.68	4.48	35.8	112	102
Carbolic	8	0.95	1.27	0.46	0.45	0.51	3.66	29.2	91	
Formaldehyde	3	0.83	1.58	0.87	0.54	0.73	4.55	36.4	114	103
Formaldehyde	7	0.81	1.45	0.50	0.45	0.52	3.72	29.7	93	
Untreated	2	0.94	1.36	0.62	0.53	0.67	4.12	32.9	103	100
Untreated	4	0.65	1.24	0.74	0.47	0.79	3.89	31.1	97	
House B. 1920										
Steam	2	0.69	1.61	0.62	0.41	0.56	3.89	31.1	118	116
Steam	6	0.69	1.48	0.65	0.42	0.49	3.73	29.8	114	
Carbolic	5	0.60	1.13	0.69	0.30	0.53	3.25	28.0	107	
Formaldehyde	8	0.98	1.00	0.44	0.35	0.50	3.27	26.2	100	
Hot Water	4	0.46	1.25	0.75	0.29	0.65	3.40	27.2	104	107
Hot Water	7	0.90	1.22	0.47	0.37	0.63	3.61	28.9	110	
Untreated	1	0.81	0.99	0.40	0.30	0.60	3.10	24.8	95	100
Untreated	3	0.58	1.14	0.72	0.34	0.68	3.46	27.7	105	

At Nursery No. 2 the average yield per acre has diminished considerably though it is still far above the general level of a few years ago previous to sterilisation being adopted. The most striking feature of this year's results is the apparent lack of benefit from the use of steam as a soil sterilising agent. Steam has given wonderful results at this particular nursery, but after a few applications it seems to lose its efficacy and better results are then obtained by the use of carbolic. The results from the steamed plots in House B. are particularly noticeable as these two plots (Nos. 3 and 7) are considered to be in the most favourable positions in the house.

Table VIII.

Soil Sterilisation Experiments. Nursery No. 2.

TREATMENT.	Yield per plant.							Total.		Relative.	
House A. 1920	Plot No.	June.	July.	Aug.	Sept.	Oct.	Nov.	Lbs. per plant.	Tons pr acre.		
Untreated	3	1.88	1.02	0.64	0.74	0.38	0.24	4.90	39.2	103	100
Untreated	7	1.64	1.06	0.59	0.66	0.48	0.21	4.64	37.1	97	
Carbolic	2	1.88	1.00	0.65	0.73	0.49	0.24	4.99	39.9	105	103
Carbolic	6	2.02	0.98	0.57	0.69	0.39	0.21	4.86	38.9	102	
Steam	1	1.84	1.13	0.72	0.74	0.47	0.22	5.12	41.0	107	100
Steam	5	1.77	1.00	0.56	0.54	0.34	0.21	4.42	35.4	93	
Hot Water	4	1.86	1.12	0.61	0.62	0.39	0.21	4.81	38.5	101	108
Hot Water	8	1.90	1.27	0.74	0.86	0.52	0.26	5.54	44.3	116	
House B. 1920											
Untreated	1	1.84	1.15	0.78	0.81	0.41	0.22	5.21	41.7	108	100
Untreated	5	1.67	1.06	0.65	0.61	0.27	0.22	4.48	35.8	92	
Carbolic	4	1.90	1.10	0.64	0.54	0.27	0.17	4.62	36.9	95	103
Carbolic	8	2.01	1.18	0.73	0.77	0.48	0.23	5.40	43.2	111	
Steam	3	1.78	0.98	0.61	0.47	0.24	0.09	4.17	33.4	86	90
Steam	7	1.84	1.06	0.63	0.58	0.28	0.13	4.52	36.1	93	
Hot Water	2	1.99	1.22	0.71	0.75	0.35	0.18	5.20	41.6	107	104
Hot Water	6	1.96	1.23	0.65	0.65	0.25	0.16	4.90	39.2	101	

Entomologist's Report.

Control of the Greenhouse White Fly on Tomatoes.

The Greenhouse White Fly, *Asterochiton (Aleurodes) vaporariorum*, is probably the most serious insect pest of the tomato under glass. When it infests the seedlings in the Spring it has the power utterly to destroy the crop by the end of the Summer. The plants grow away from it until the fruit begins to swell and the pest then gains the upper hand. At the best not more than four or five trusses of fruit can be picked and all the fruit has to be wiped before it can be marketed.

As an instance of its damage the following experiment is quoted. Thirty-four young tomato plants (Kondine) were infested when 8 inches high by placing them on May 6th in a section of a greenhouse in which were also placed three small heavily infested plants, one tomato and two French beans. They were then potted in 12 inch pots and on half of them the infestation was allowed to develop unchecked while the remaining seventeen plants were removed about once a fortnight to another section of the greenhouse and fumigated with hydrocyanic acid gas in order to keep the pest on them checked. Apart from these fumigations the plants received the same treatment. The last fruit picking on the heavily infested series was on August 24th when the plants, being practically dead, were destroyed. The total crop averaged 1 lb. 11 ozs. per plant. The other plants were still vigorous at the last fruit picking on October 8th, the total crop averaging practically 4 lbs. per plant. The monthly yield of the two series is shown in Table I.

Table I.

An estimation by weight of fruit of the effect of an unchecked Infestation of White Fly on Tomatoes, 17 plants in each Series.

	A. Cyanided 8 times. Lbs.	ozs.	B. Not treated. Lbs.	ozs.
July	22	$10\frac{3}{4}$	21	$9\frac{1}{2}$
August	18	$2\frac{1}{4}$	8	$5\frac{1}{4}$
September	8	13	—	—
October	16	14	—	—
Total	66	8	29	$14\frac{3}{4}$

Not uncommonly tomato plants in a trade nursery are as badly infested as these, and it may be fairly stated that if the plants are infested early and the infestation is not checked a loss of more than half the crop will be the result.

Life History.

Three stages in the life history of the insect must be distinguished by the grower, the egg, the scale and the adult fly. All are found on the lower surfaces of the leaves, and all are covered with wax.

The Egg.

The egg is very small and can hardly be seen with the naked eye. It is oval and a short stalk sticks into the leaf and holds it in place. It is whitish when first laid but darkens in two or three days and then turns black. On smooth leaves, like those of geraniums and beans, the eggs are laid in small circles, but on hairy leaves, like those of the tomato, they are

scattered. In hot weather in the greenhouse (mean shade temperature 75-80° F.) they hatch in 8 days and never in less. In warm weather (mean temperature 63-65°) they hatch in 17-21 days, while the longest incubation period we have recorded in a heated greenhouse was 25 days with a mean temperature of 60°.

The Scale.

This stage corresponds to two stages in the life history of an insect such as a moth, the caterpillar or larva and the chrysalis or pupa, and it is hard to say where one ends and the other begins. Not uncommonly the grower calls this condition the "egg," and it is often so misnamed in correspondence in trade papers. The scales may be destroyed by fumigation, but the eggs cannot be killed by any greenhouse fumigant known which does not also kill the plant.

The scales are small, oval and flat at first, and are somewhat transparent with two opaque yellowish bodies near the hinder end. They have six legs and a pair of small red eyes. The mouth has a long stabber which is pushed into the leaf and up which the sap is drawn. The scale moves a short distance on the leaf and then settles down to feed and does not move about any more. It casts its skin three times, and after the third time takes on a new appearance and then becomes easy to see. It grows thick and opaque and from its back a number of waxen rods develop. With a lens the large eyes of the adult can be seen and three places on its edge where the otherwise smooth wax looks white and is porous. Through these three places the insect draws air in and out. In this condition the legs and wings of the next stage develop until it becomes an adult resting in a waxen case. At this point it corresponds to the chrysalis of the moth.

Throughout the scale stage, and in the adult condition also, the insect is continually throwing out excreta in the form of a fine spray called honey dew. This falls onto the leaves and fruit on which it forms a film. The dew is very rich in sugars and in the film a growth of sooty moulds develop which keeps the sunlight from the leaves. It is by this indirect means that the insect mainly damages the plants.

In warm weather in the greenhouse this scale stage takes from 21 to 27 days from the hatching of the egg to the emergence of the adult. In Winter in the heated greenhouse it may take up to 45 days. Fortunately from the point of view of the control at any ordinary greenhouse temperature this period is longer than that occupied in the hatching of the eggs at the same temperature.

The rate of multiplication in the greenhouses from Spring to Autumn is about 120-fold per month.

The adult.

The adult insect is too familiar to nurserymen to make much description of it necessary. It is a fragile yellow bodied insect, and when it emerges from the scale its four wings are transparent, but it quickly covers these over with wax and takes on its well-known snowy appearance. Mainly they congregate on the younger foliage of the plant but in bad infestations they are found laying eggs on every leaf. Both sexes are long lived, males having been found to survive 45 days and females 100 days. Throughout life the female lays eggs at the rate of 4—7 a day, and the largest number one has been known to lay was 534. If the female has been mated the eggs result in offspring in the approximate proportions of two females to one male. If it is not mated the offspring are all males.

The white fly will feed and lay eggs on every plant and weed that has been tested, but it has a strong preference for the following:—cucumbers, tomatoes, French beans, potatoes, salvias, calceolarias, and on these practically every egg laid becomes an adult. On fuchsias, begonias, geraniums, arums, and such hard-leaved plants the majority of the scales die, but enough survive to carry on the pest, and the same is true of the grape vine. In the case of the chrysanthemum little breeding goes on upon the young foliage but the insect breeds successfully on the old leaves. On carnations, narcissus, tulips and grasses none of the scales seem to mature, but the adult can live long on these. The inclusion of the cucumber among the most favoured plants needs a word of explanation as the insect is not considered a pest of this crop. It is sometimes found on the plants in the cucumber houses early and late in the year, but for the greater part of the growing season it is rarely seen on them, Evidently the atmosphere of the houses is unsuited to the insect which becomes distressed when the temperature approaches 100°F. On cucumbers and melons grown in cool houses the pest may be very serious.

It is important to notice that in all its stages this white fly is dependent on the living plant. For this reason it is not fully adapted to the English climate as a severe winter in which all foliage except that of leathery evergreens is cut down by frost would exterminate it out of doors. Our experiments show that it can survive mild winters outside in the egg condition, the eggs delaying hatching until the Spring. In spite of this there is no doubt that the vast swarms which are found outside in Summer and Autumn are derived from those which have been fostered over the Winter in greenhouses and cold frames. Where such swarms exist the scales may be found to a greater or less extent on most plants and shrubs

and on some trees. The plants most favoured by them in the flower garden are the hollyhock and the calceolaria; in the vegetable garden, French and runner beans and marrows; and among weeds, the stinging nettle.

Growers of mixed crops suffer most from the white fly as their greenhouses are never free from foliage of some sort. Those who only grow tomatoes, raise all their own seedlings, and pay due care to the clearing of their houses of weeds in the Winter do not usually see the insect on their plants till well on in May. This is the time when it begins to move about outside and the first appearance of the pest consists of a few individuals on the plants near the doors. Under these circumstances the insect cannot give serious trouble till the end of the Summer. Conditions vary greatly, however, in accordance with the nearness and character of the neighbouring nurseries.

Control.

General Precautions.

Always propagate in an empty greenhouse. In some localities it is a practice to sow early seed at one end of a house containing infested plants. Where tomatoes form the staple summer crop this is too big a risk to run, as infestation of the seedlings is certain.

Never propagate from cuttings of old tomato plants which have been infested. Propagation by cuttings is not a common practice, but it is occasionally done, and in some instances the result has been disastrous to the grower and his neighbours.

When seedlings are purchased a guarantee should be obtained with them that the house from which they come is free from white fly. We are aware of instances where very serious infestations have followed the purchase of young plants carrying the insect. The same precaution should be observed in employing any bedding out plants which have been under glass during the Winter as the pest is certainly largely spread about by means of these.

The grower of mixed plants should make certain that the houses into which he puts his tomatoes are free of the pest. It is only necessary to clear everything out of the houses, dig them over to bury any weeds and leave them empty for a week with the heat on. Any white fly present will then be starved to death. If the interval is less than a week the houses should be fumigated with cyanide. Sulphur fumigations are not nearly so effective. As mentioned above the grower who specializes in tomatoes will generally make a clean start by the system of growing as practised in the Lea Valley. All trimmings from infested houses and the plants at the end of the season should be burnt as early as possible.

Remedies.

When the pest is established the only means of exterminating it on the growing crop is by fumigation. Apart from their expense fumigations by means of tobacco preparations are of little use to the trade grower. They drive enormous numbers of the flies outside and many which fall are only stupified and regain the plants when they recover.

Tetrachlorethane is a good fumigant for white fly and its application is very simple. It is a liquid which should be poured down the middle of the house in the evening, half a pint being used to each thousand cubic feet of space. The house should then be kept closed as long as possible without harming the plants. In cold or dull weather when the greenhouse may be kept closed through the following day and night it will kill all stages of the insect except the eggs, and the operation must be repeated as in the case of cyanide. If the house can be kept closed for only 15 hours or so the very large majority of the flies and scales will be killed. It is not an intensely poisonous substance like cyanide and it may be used in greenhouses opening into dwellings, the intervening door being of course kept shut. It does no damage to the ordinary greenhouse plants, including tomatoes. In cheapness it will not compete with cyanide, its cost being about ten times as great.

Cyaniding Tomato Houses.

Fumigation by means of cyanide is the only really practical cure for white fly in trade nurseries. The materials required cost about one penny per thousand cubic feet of space, and when these are properly used two fumigations will give complete control over the pest for the season, however bad the infestation may be. It has become unpopular in recent years because it has been improperly used, and damage to the plants and failure to control the pest have often been the result. It is of course a very poisonous substance and it must never be carelessly handled, but there is no danger if the instructions are followed exactly. The following instructions refer especially to tomato plants, but they apply also to all ordinary greenhouse plants, and all of these on which the gas has been tested are less liable to damage than the tomato. Blooms are more resistant than foliage and have never shown damage after careful fumigation. Seedlings such as sweet peas, asters, etc., do not suffer damage, and vines with young foliage, with setting fruit, and mature fruit have also been cyanided without any harmful effects in any of the three conditions.

Interval between Fumigations.

The first fumigation destroys all the adults and the scales, but no eggs. The second fumigation should follow when all the eggs have hatched but before any of these have become adult. The second should therefore follow the first as nearly as possible on the following days:—

In hot weather (mean greenhouse shade temperature 72° upwards) on the 14th day.

In warm weather (mean greenhouse shade temperature 65-72°) on the 21st day.

In cool weather (mean greenhouse shade temperature up to 64°) on the 25th day.

Condition of Plants.

Hard growing plants will stand the gas better than soft sappy ones but the softest tomato plant will not be damaged by the gas if it requires water at the time of fumigation. When the plants have thick sappy foliage and the young leaves at the crown are very strongly curled backwards and cannot be straightened out easily they are almost certain to suffer. Similarly thin leaved plants are very liable to damage if the young leaves point straight upwards so that the crown is closed in at dusk. These are conditions of turgidity and show that the water is abundant at the roots. When water is withheld the plants gradually pass out of these conditions and there is a time before they begin to wilt when they may be cyanided with perfect safety. When they are actually wilting they will stand very strong doses at high temperatures without damage to the foliage.

It is not possible to form any hard and fast rules as to the length of time that water should be withheld before the fumigation as this varies so much with the weather, the character of the soil, and the conditions under which the plants are grown, in borders or in pots. The individual grower must use his own judgment and dry off the roots just so far as he can without damaging the setting of the fruit. It is generally recognised that no drying off is possible until the plants have been stopped, and fortunately, if a clean start has been made, cyaniding is never necessary before this. When it is necessary to fumigate unstopped plants this should be done with great caution and only half the quantities of cyanide mentioned below should be given, *i.e.*, 1/10th or 1/8th oz. to the 1,000 cubic feet. These small doses will not exterminate the pest but they will destroy more than 75% of the adults and scales and so check the infestation until the plants have been stopped and larger quantities of cyanide may be used.

Atmospheric Conditions.

The temperature of the houses should be rather low for the fumigation, below 60° if possible. Artificial heat is undesirable on warm nights. Even when the boiler heat is cut off however the grower will generally find that his thermometer stands at about 65° at dusk in Summer and early Autumn. This makes it all the more important that the plants should be brought into the right condition before they are fumigated. If they are turgid and the temperature is above 60° they are certain to be injured.

Rain, the humidity of the air in the greenhouses, and moisture on the foliage may be disregarded as they do not affect the safety of the plants or the control of the pest. Windy nights should be avoided as the air moving quickly over the houses causes more of the gas to escape than when there is little draught.

Length of Fumigation.

It has been found that fumigations with small quantities of cyanide lasting through the night are more effective against the pest and are less likely to damage the plants than the large charges necessary if the operation lasts from one to three hours only. Small charges are also safer to the operators and cost at most only half as much for materials.

Time of Day.

The gas must not be in the houses during full daylight or the plants are almost certain to be damaged. Sunlight destroys the gas and so the control fails. The operation should commence at dusk and the doors and ventilators should be opened at dawn to allow the gas to escape.

Measurement of Houses.

The houses should be measured accurately in thousands of cubic feet. The capacity is found by multiplying the area of the house by its average height. The average height is found by adding the height to the gutter and the height to the ridge together and dividing this by two. (Example given below).

Apparatus and Materials.

The following apparatus is required:—

A glass measure graduated in ounces.
A delicate balance, such as a tobacconist's or letter scale, unless the cyanide is bought in weighed packets.
Glazed earthenware jars or basins, jam jars being suitable.
If plugged plant pots are used the results are never satisfactory as some of the acid escapes from them.

The materials to be obtained are:—

Concentrated Sulphuric Acid (Brown Oil of Vitriol) with a specific gravity of about 1.8. A pint should weigh about 36 ounces. Sodium Cyanide, "High Grade," 98 per cent. purity. This is often called "130% Cyanide" in reference to the more expensive and relatively weaker Potassium Cyanide. It is often more convenient to purchase the cyanide in weighed packets. If it is obtained in this condition the material must be emptied out of the papers before being placed in the acid. When it is dropped in enclosed in paper only part of the gas is given off and the remainder of the cyanide chars. This applies only to paper and cardboard packets and not to the metal "Safety" container which may be used if desired, but in this case the maker's instructions as regards the acid used must be followed and not those given below which refer only to loose cyanide.

Cyanide should be kept in paper in a tin with a tightly fitting lid as it absorbs water from the air and deteriorates if exposed.

The materials are used in the following proportions:— Water, 3 fluid ounces, Sulphuric acid, 1½ fluid ounces, Sodium cyanide, 1 ounce. When the acid and water are mixed the water should be put into the jar first and the acid added slowly; otherwise drops may be thrown out of the vessel and injure the eyes. In any case great heat is developed and unless the vessel in which the mixing is done will withstand this it is liable to crack. Glazed earthenware vessels are most suitable.

Amount of Cyanide required.

Houses in blocks require less cyanide than isolated houses in the same state of repair because the latter have a greater outside surface and so more leakage of the gas takes place. Similarly low houses such as cucumber houses require rather more than tomato houses because they have a greater outside surface in proportion to their capacity. As the construction of the houses varies so much it is not possible to give an exact table showing the quantities required but the following will prove a reliable guide. For isolated houses, "cucumber houses" in blocks, and leaky tomato houses in blocks use ¼ oz. of cyanide for each 1,000 cubic feet, for tight high houses in blocks use ⅓ oz. to each 1,000 cubic feet. (See also under "Condition of Plants" above).

It is recommended strongly that the grower should keep a book in which he notes the amounts used in each house and the result both as to the extermination of the pest and any damage which may be done to the plants. When it becomes necessary to fumigate the house again a reference to this will

show whether too much or too little was used. If the result was unsatisfactory as regards the pest another charge should be added: if it was satisfactory as regards the pest but the plants were damaged, and the damage was not due to any of the errors pointed out above, then one charge less should be used. The troublesome calculations need only be made once if this system is followed.

Size of Charges.

The amount to be put into each jar varies with the width of the house. The best distribution of the gas is obtained if the distance between the jars is about the same as the width of the house. This is approximately the case if the amount of cyanide in each jar is as follows:—

For houses up to 14 feet wide $\frac{1}{4}$ oz.
„ „ from 14 to 20 feet wide $\frac{1}{2}$ oz.
„ „ over 20 feet wide 1 oz.

With tomatoes it is not advisable to employ larger charges than 1 oz. or the concentration of the gas may damage the plants close to the cyaniding vessels.

Mode of Operation.

The following example is given to summarise the foregoing information and to show the order in which the steps should be taken. If these instructions are followed exactly the operation may be carried out without the slightest discomfort.

EXAMPLE.—Required to fumigate a block of houses each 200 ft. by 27 ft., height to ridge $12\frac{1}{2}$ ft., height to gutter 4 ft., giving $\frac{1}{4}$ oz. of cyanide to each 1,000 cubic feet.
Average height $12\frac{1}{2} + 4 = 16\frac{1}{2}$, $\div 2 = 8\frac{1}{4}$ ft.
Area: $200 \times 27 = 5{,}400$ sq. ft. Capacity: $5{,}400 \times 8\frac{1}{4} = 44{,}550$ cubic ft., say 44,000.
11 jars, 11 ozs. of cyanide and $16\frac{1}{2}$ fluid ozs. of sulphuric acid required for each house.

Make sure that the plants need water. In the afternoon put in each jar first 3 fluid ozs. of water, then $1\frac{1}{2}$ fluid ozs. of acid and place the jars at equal distances down the centres of the houses. Weigh out the cyanide in ounces and wrap each charge as weighed in a piece of paper. Cut off the heat unless the night is likely to be very cold. At dusk close the ventilators and one man to each house passes down and places by the jar a charge of cyanide fully exposed on a piece of paper. When all have reached the far ends a signal is given and the operators pass down the houses at an ordinary walking pace

and as they come to the jars tilt the cyanide loose into the acid. The doors are then locked. At dawn open the houses and leave for an hour before entering, then collect the jars, empty the contents down a drain and rinse them out. The plants may now be watered freely.

Report of the Mycologist.

The investigations of this year have been concerned mainly with "Sleepy disease" of the tomato, and the problem of water contaminations in relation to plant disease. Further work has also been done in connection with "Stripe" disease of the tomato. Many diseases have been brought to notice this year, the majority being similar to those listed in the 1919 Report. Several diseases not previously reported have been noted as below.

Host.	Disease.	Parasite.
Tomato.	Sclerotium disease.	*Sclerotinia sclerotiorum.*
Cucumber.	,, ,,	,, ,,
Cucumber.	"Gummosis" of fruit.	*Cladosporium sp.*
Cineraria.	Foot rot.	*Phytophthora cryptogea.*
Geum sp.	Root rot.	*Rhizoctonia solani.*
Tulip bulb.	Dry rot.	*Fusarium sp.*
Strawberry.	Soft rot or Leak.	*Botrytis sp.*

"Sleepy Disease" or Wilt of the Tomato.

The disease of tomatoes, known as Wilt or Sleepy Disease, is found throughout the whole of the British Isles where tomatoes are grown and is the cause of considerable financial losses to the tomato industry. Under the normal temperature conditions of these parts the chief cause of the disease is a fungus, Verticillium albo-atrum, but under exceptionally high temperatures another fungus, Fusarium lycopersici, may be the cause. Verticillium wilt first appears about the middle of April and increases in intensity up to the second and third week in May when it reaches its maximum. In normal Summer temperatures the attacks die down during the second half of June, July and August and re-appear at the end of September when the plants die prematurely. Fusarium wilt occurs at the height of the season, usually in July and August. In epidemic cases the percentage of diseased plants in a nursery may be as high as 90% but generally it varies from 5% to 20% and frequently only a few plants may be attacked. The disease is worst at the ends of the houses, especially near the doors which are most frequently used; while plants in the warm portions of the nursery are freer

from the disease than those in the cooler parts. Plants grown "hard" are more susceptible to the disease than the softer succulent types, and consequently varieties like Kondine Red show a strong susceptibility. Plants which have been starved in the early stages or suffered a prolonged check show a high percentage of disease. Temperature is a determining factor in the incidence of the disease. Verticillium grows best at a mean temperature of 70°F.—72°F. while Fusarium lycopersici finds its optimum at a mean of 82°F.—84°F. Most varieties are susceptible to Verticillium wilt and so far as our tests have gone Manx Marvel is the only variety that is highly resistant.

Symptoms of the disease.

The term "Sleepy Disease" aptly describes the appearance of the diseased plants. They are usually stunted in habit, but not invariably so, and the internodes are badly developed, especially near the top, where the leaves form a rosette. When conditions are most favourable to the fungus the symptoms appear quite suddenly. The plants may be perfectly turgid and green with no signs of yellowing when, without any warning, the leaves droop and become limp. During the night the plants may recover their turgidity, only to wilt again as the morning advances. The plants wither from the base upwards and finally die. When conditions are less favourable to the fungus the process of death is much slower, perhaps lasting many weeks. Yellow blotches appear first on the lowest leaves and then on those above as the disease advances. The yellow blotches spread and the leaves dry up. Under these conditions the leaves do not wilt but are slowly desiccated from the base of the plant to the top. Finally death ensues. On cutting open the stem of a diseased plant the wood is seen to be discoloured; the colour varying from light to dark brown. The discolouration of the stem may be followed to the root and the point of entrance of the fungus into the plant may be distinguished by the intense browning at that point. The disease organisms hibernate in the soil or compost from season to season and infect the young roots as they develop. Entrance to the plant is assisted by wounds, but experiment has shown that such are not essential for infection, Verticillium having the power to invade roots absolutely free from wounds. The fungus destroys the cortex at the point of entrance and entering the wood passes up into the stem. Here it is found solely in the woody parts. When the plant dies, the fungus leaves the vessels and penetrating the cortex, forms at the base of the stem a white external growth. This is the active fruiting stage, and the spores are readily blown about, enabling a rapid spread of the fungus. Occasionally the fungus may penetrate

the fruit causing a soft rot. Infection rarely takes place in the seedboxes or pots, but almost entirely after the plants have been placed in the houses.

The Causal Organism.

During 1919-20, 427 plants from different parts of England, Scotland and the Channel Islands were examined. Of these, 96% were attacked by Verticillium albo-atrum and 4% by Fusarium lycopersici. The causal organism was isolated, grown in pure culture and tested for pathogenicity by suitable inoculation experiments. The inoculated plants showed first symptoms of the disease in eight to ten days and complete wilt in six weeks, while suitable controls remained perfectly healthy. Having obtained a good active stock of the fungus, experiments were set up to determine the relation of disease attacks to different environmental conditions.

(1) Monthly inoculations throughout the year.

Tomato plants six weeks old were used in all experiments unless otherwise specified. In this case twelve plants were inoculated each month and were grown under similar conditions throughout the year, except for such alteration as was caused by seasonal variation. The results are shown in Table I.

Table I.

Date inoculated.	No. of days after inoculation that symptoms appeared.	Pathological symptoms.
27/3/19	15	Complete wilt with slight yellowing
26/4/19	14	Complete wilt, no yellowing
25/5/19	10	„ „ „ „
27/6/19	No wilt in 10 weeks	Lowest 9 leaves turned yellow and partially dried up
25/7/19	„ „ „ „ „	Lowest 3 leaves desiccated
25/8/19	53	Complete desiccation of leaves from base upwards
22/9/19	40	Bottom 4 leaves desiccated
22/10/19	26	Complete wilt with practically no yellowing

The above results indicate that the conditions during the months of June, July and August are unfavourable to the rapid progress of the fungus in the plant.

(2) The relation of the progress of the disease to the character of the plant.

The results of inoculating plants in different stages of growth and of varying degrees of hardness and softness of growth are shown in Table II.

Table II.

TYPE OF PLANT USED.	Mean diameter of stem base in cms.	No. of plants.	Age in weeks.	Date of inoculation.	Average No. of days between inoculation and first symptoms.	Average No. of days between inoculation and total wilt.
"Comet" soft growth	0.8	12	6	4/4/20	21	39
" " "	1.05	12	8	4/4/20	21	47
" " "	1.2	12	10	18/4/20	21	53
" hard growth	0.45	12	6	4/4/20	10	24
" " "	0.7	12	8	4/4/20	8	29
" " "	0.75	12	10	18/4/20	8	37
" starved growth ...	0.45	12	6	4/4/20	8	20

The above observations show that plants of "hard" growth, with a thin stem, or plants obviously starved most readily succumb to the disease.

Cross Inoculations.

Potato.—Solanum tuberosum.

Twenty-four Epicure potatoes were sprouted and, after the removal of all but two shoots, were planted in fresh loam in eight-inch pots. Inoculations were made when the shoots were about six inches long. Twelve plants were inoculated by pricking into the base of the stem, under aseptic conditions, a small piece of mycelium from a pure culture of Verticillium and covering with tinfoil. Twelve plants were left as controls. After an average of fourteen days the first symptoms of the disease appeared. The leaves developed yellow patches and wilted. After forty-eight days eleven out of the twelve plants were dead, all the leaves being withered. Verticillium was re-isolated from the diseased potato stems, and proved to be

identical with the original culture used in the inoculation The control plants remained perfectly healthy throughout the whole of the experiment, and no fungus could be found in them.

Egg plants.—Solanum melongena.

Twelve young egg plants, about six inches high, were inoculated under aseptic conditions by pricking into the base of the stem a small piece of mycelium from a pure culture of Verticillium and covering with tinfoil. Twelve were left as controls. The first symptoms of disease appeared on an average of ten days after inoculation. The lowest leaves became flaccid in parts, so that portions of the lamina were turgid and the remainder wilted. The latter portions became straw coloured, and the wilt increased until the whole leaf hung limp from the petiole. Gradually the entire plant became wilted, the disease progressing from the base upwards. Forty-three days after inoculation nine plants were completely wilted and three badly wilted. Cultures of Verticillium were readily obtained from the browned wood inside the wilted stems. The control plants remained quite healthy and no fungus could be obtained from them.

Snapdragon.—Antirrhinum sp.

Twelve young plants four inches high were inoculated by pricking into the base of the stem a small piece of mycelium from a pure culture of Verticillium and covering with tinfoil. Twelve controls were made. In this case there was no yellowing of the leaves but they wilted and hung limp from the petiole. Forty-eight days after inoculation eleven plants were completely withered and one badly wilted. The fungus was readily re-isolated from the diseased plants, and proved to be identical with the original culture. The control plants remained perfectly healthy.

Cucumber.—Cucumis sativus.

Twelve young cucumber plants about six inches high were inoculated under aseptic conditions by pricking a small piece of mycelium into the base of the stem and covering with tinfoil. Twelve controls were made. After nine days the first symptoms of the disease appeared as yellow patches on the cotyledons and first pair of leaves. These patches wilted, and dried up. Gradually the plant became desiccated from the base upwards and after thirty-five days all twelve plants were completely withered. The fungus was readily re-isolated from the dead plants. All control plants remained perfectly healthy.

Sycamore.—Acer sp.

Twelve young sycamore seedlings about six inches high were inoculated near the base of the stem by pricking in a small piece of mycelium. Twelve controls were set up. After twelve days the first pair of leaves began to show signs of desiccation, light brown patches appearing at different places on the lamina, usually towards the tip. These patches dried up, the leaves became distorted and finally withered completely. Desiccation proceeded slowly from the base upwards until ninety-two days after inoculation, when the leaves were completely withered. The diseased plants were much dwarfed in comparison with the healthy controls. Verticillium was re-isolated from the interior of the stems.

Cotton.—Gossypium herbaceum.

Twelve young cotton seedlings about four inches high were inoculated by a stab close to the ground level. Twelve controls were made. After sixteen days the first pair of leaves began to show signs of desiccation. Typical light brown patches appeared on the leaves, which became distorted and finally withered. After thirty-five days most of the leaves were desiccated. The controls remained quite healthy, and were twice the height of the inoculated plants. Verticillium was readily re-isolated from the diseased plants.

Pepper Plant.—Capsicum sp.

Twelve pepper plant seedlings were inoculated with Verticillium by a stab near the base, and twelve controls were made. The fungus made slow progress; the first symptoms appearing thirty days after the inoculation, when one leaf per plant wilted. There was no brown discolouration of the leaves which simply became flaccid and drooped. After thirty-five days three leaves per plant were wilted. The inoculated plants were stunted in comparison with the healthy controls.

Elm.—Ulmus sp.

Six young elm seedlings were inoculated by a stab near he base of the stem, and six left as controls. Even after four months there was no sign of yellowing or wilting in the inoculated plants but they were uniformly shorter than the controls, and Verticillium was re-isolated from the stems two inches above the point of inoculation. The above experiments show that Verticillium albo-atrum has a wide range of host plants, any of which may serve as a source of infection to the tomato.

Temperature Relations.

The observations which have been taken upon the previously described inoculation experiments, indicated an intimate relation between temperature conditions and successful inoculation results, and showed the necessity for further investigation upon this relationship. As a series of glasshouses, where different temperatures could be constantly maintained, was not available, inoculated plants (hypocotyl stab) were placed in different positions in the experimental houses, corridors, etc., under different average temperature conditions. Twelve plants were placed in each position, and the average temperatures were calculated from readings taken twice daily from maximum and minimum thermometers placed beside the plants. The final observations, shown in the following tables, were taken twenty-one days after inoculation, and where figures are given they represent the average obtained from twelve plants.

Table III.

	Frame.	Corridor.	Tomato House.	Cucumber House.
Average temp. F. ...	54.6°	62.4°	70.3°	77.2°
Absolute Min. F. ...	42°	52°	54°	69°
Absolute Max. F. ...	69°	73°	82°	92°
Date of inoculation ...	14/4/20	14/4/20	14/4/20	14/4/20
No. of days from inoculation	21	21	21	21
Ratio of wilted to total leaves	$\frac{0}{10}$	$\frac{6}{12}$	$\frac{8}{12}$	$\frac{0}{12}$
Height of discoloured wood above stab ...	15 cms.	26 cms.	28 cms.	9 cms.
No. of days from inoculation until complete wilt	49	28	28	No wilt after 80 days.

While the results obtained are open to criticism because of the wide range of temperature to which the plants were submitted in any one position, certain facts emerge which have been fully confirmed by observations on commercial nurseries. Chief among these are the beneficial effects which shade and temperatures above 75°F. have upon plants suffering from wilt. Table III. shows that average

temperatures of 63°F. and 70°F. are favourable to the rapid progress of the disease, that of 54°F. is unfavourable, while that of 77°F. practically inhibits it. It will be seen that the organism has travelled most rapidly up the stem, as indicated by the browning of the wood, at 63°F. and 70°F., and at these temperatures also complete wilt occurred most rapidly. The results shown in Table IV., while confirming the temperature

Table IV.

	Frame.	Tomato House.		Cucumber House.	
		Unshaded.	Shaded.	Unshaded.	Shaded.
Date of inoculation	14/4/20	14/4/20	14/4/20	14/4/20	14/4/20
No. of days from inoculation	21	21	21	21	21
Average temperature	62.4°F.	71.5°F.	68.9°F.	79.3°F.	77.1°F.
Ratio of wilted leaves to total leaves	6/10	3/10	0/10	0/10	0/10

relations shown in the preceding Table, also show the beneficial effect of shade. While plants in the unshaded house readily wilted, those in the shaded house, although the temperature was favourable to the disease, did not wilt.

General observations also have shown that temperatures between 60°F. and 75°F. with an optimum of 70—73°F. are favourable to the rapid progress of Verticillium wilt, which below 60°F. and above 75°F. is exceedingly slow, while suitable shading counteracts the effect of low temperatures.

A series of experiments were next arranged in which wilted plants were transferred to high temperatures to ascertain if they would recover, and if such a recovery would continue when they were returned to lower temperatures. The results are tabulated below.

The following results (Table V.) indicate that wilted plants recover when the average temperature is raised to 77°F. and they are shaded. When such a temperature is operative for a short time the effect is not a lasting one, for the plants rapidly wilt again when the temperature is lowered. Longer exposures to the high temperature produce a more lasting result, for after 75 days at 77°F. the plants remained turgid for 30 days at a temperature favourable to wilt. Table VI. compares the percentage of wilted plants which recover when transferred to a shaded house at an average temperature of 77°F., with that of similar plants transferred to an unshaded house at the same average temperature.

Table V.

No. of wilted plants.	Length of time in shaded cucumber house. Average temp. 77°F.	Effect of high temperature.	Length of time after returning to average temp 70°F. before plants again wilted.
12	1 day.	Recovered.	15 hours.
12	2 days.	,,	15 ,,
12	7 ,,	,,	2 days.
12	14 ,,	,,	3 ,,
12	30 ,,	,,	16 ,,
12	75 ,,	,,	30 ,,

Table VI.

No. of wilted plants.	No. of days wilt has been visible prior to experiment.	% Recovered in shaded cucumber house. Average temp. 77°F.	% Recovered in unshaded cucumber house. Average temp. 77°F.
20	2	100	100
20	7	100	100
20	14	100	100
20	21	100	90
20	30	100	80

Plants in different stages of wilt were used, from a series where the wilt was just commencing to show to a series in an advanced stage after 30 days wilting. All the plants recovered in the shaded house, but only a percentage recovered in that which was not shaded. The plants which did not recover in the unshaded house, being the badly wilted ones, were probably desiccated before they had a chance to recover.

These observations appear to justify the conclusion that temperature is a most important factor, while shading is valuable because it assists the plant by reducing transpiration. The minimum, optimum and maximum temperature for

growth in pure culture of the strains of *Verticillium albo-atrum* utilised for the inoculations were 40°F., 74°F. and 86°F. respectively. It will be seen, therefore, that the optimum temperature for infection coincides approximately with the optimum temperature for growth in pure culture. Verticillium wilt is distinctly a disease of low temperatures and is most severe in Spring and Autumn.

Shade.

Shade, as we have seen, has a beneficial effect upon the resistance of the host to the disease. Probably this is due to retarded transpiration and consequently to the decreased rate of conduction of the water in the vessels, so that the toxic products excreted by the fungus are not carried up the plant in such large amounts.

Soil Factors.

Experiments carried out with soils of different types show that Verticillium wilt is not restricted to any particular type.

Generally speaking, plants on soils which contain a large amount of humus yield a greater amount of disease than those growing on soils of a poorer nature.

Clay soils, in virtue of their greater water-holding capacity, are cooler than sandy soils, and plants grown upon them are more prone to wilt than those grown on the latter.

Control.

Further work is in progress to determine a suitable chemical agent which will sterilise the soil and effectively cleanse it of the wilt-producing organisms. Investigations are also being carried out on the efficacy of manurial treatment in rendering the plants resistant to fungal attack, but it is too early to suggest any treatment.

Cultural Methods.

Cultural methods for the control of the wilt have been devised, and have been tested with promising results.

It is commonly held by pathologists that plants exhibiting hard growth are more resistant to disease than the more succulent types, but observations on wilt disease show in this case the reverse to be true, the harder growing varieties succumbing more readily than the more succulent ones. The only variety, Manx Marvel, which so far has proved highly resistant to *Verticillium* shows a distinctly free growth with thick stems and large leaves.

It has also been specially noted that plants, starved in the early stages, or having suffered from a severe check are highly susceptible. It has been mentioned previously that the average temperature of the air and soil are limiting factors

in the incidence of the disease. The disease is first seen in Spring, when the temperature is low, but with the coming of the higher Summer temperature the wilted plants recover, and the percentage mortality of the plants infected in the Spring depends upon the length of time the cold weather lasts.

The incubation period for the disease varies from eight to twenty days under favourable conditions and complete wilt and death occurs in from six to eight weeks after the first symptoms appear, if conditions are favourable for the fungus. Should the temperature be sufficiently raised before the plant dies, it will recover and produce a satisfactory crop during such time as the temperature remains high. Once the temperature drops in the Autumn, wilt reappears, and the plant dies prematurely. Early Summer temperatures, therefore, enable the plants to resist the fungus. It will at once be evident that good results may be obtained by artificially shortening the period of low temperature, and in glasshouses this may be done by increasing the boiler heat, and closing down the houses in the middle of the day.

The following cultural methods for controlling the disease have yielded satisfactory results. As soon as the wilt appears and it is proved that *Verticillium albo-atrum* is the pathogen, the average temperature of the houses should be raised above 77°F. by suitably increasing the boiler heat, regulating the ventilation and by closing down the houses from two to four hours in the middle of the day. A light dressing of whitewash on the glass makes the conditions still more favourable for the plants. As little water as possible should be given to the roots, as heavy watering merely aggravates the wilting, but a light overhead damping helps the wilted plants to recover. The plants should be encouraged to make fresh roots above the original diseased ones, by placing fresh soil round the base of the plant.

In one case sixty-eight per cent. of the plants in a nursery were showing symptoms of Wilt Disease before the above methods were enforced, but a fortnight after only ten per cent. remained wilted. In view of the fact that the low Spring temperatures are favourable to infection by *Verticillium*, some advantage might be gained by planting later than normally, so that the higher Summer temperatures may arrive by the time the plants have reached a suitable stage for infection.

Examination of the effect of soil type upon the incidence of the disease has shown that soils rich in humus yield a higher percentage of diseased plants than those of a poorer nature. Results obtained on the experimental plots at this station readily corroborate this; the greatest percentage of Verticillium wilt occurs on the plots receiving complete artificials with large amounts of dung.

The Elimination of Sources of Infection.

Too much importance cannot be laid on the fact that it is useless to sterilise the soil if centres of infection are allowed to exist in the neighbourhood of the nursery.

Certain workers have pointed out that *F. lycopersici* will develop much more rapidly in sterilised soil than in ordinary unsterilised soil. Presumably this is due to the fact that the process of sterilisation eliminates a large number of bacteria, which would otherwise check the development of the wilt organisms. We have found the same to be true for *Verticillium albo-atrum*, for plants growing in incompletely sterilised soil or re-inoculated sterilised soil yield a higher percentage of disease than those in unsterilised soil. This relation is accentuated if the soil be exceedingly rich in humus, as is the case with sterilised cucumber soil, which is frequently used for tomato propagation. The determination and elimination of infection centres thus become of vital importance. The fungal outgrowths at the base of dead diseased plants produce innumerable spores which become widely disseminated. These in themselves will not carry the fungus over the period of Winter, being destroyed by desiccation, but they readily germinate, and feeding on decaying plant material, produce carbonised hyphæ and microsclerotia, which are able to withstand Winter conditions. Close examination has been made of small pieces of plant remains which have been unearthed from nursery soils, after the crop has been removed, and numerous tomato pathogens, including *Verticillium albo-atrum*, have been found upon them. Thus it is important to remove completely all dead plants before the fungal outgrowths appear, and in the process of cleaning up the nursery when the crop is finished, to remove carefully as much as possible of the dead plant-remains. Careful attention to these matters will prevent the rapid spread of the disease. The best way to remove the crop, when completed, is to sever each plant about three inches from the ground before attempting to remove the roots. If the surface is quite clean before the roots are removed there is less chance of incorporating diseased material in the soil and the roots may then be carefully taken up, leaving behind only the very fine rootlets.

Another source of infection which becomes more and more evident, is the contamination carried in "strikes" or baskets, and a considerable number of cases have been noted, where infection with various diseases came from these articles. Such baskets may be so mixed at the market, that when they are returned, those from one nursery are sent to another, and so disease is spread. Baskets should not be taken near to the growing plants for fear of introducing some new trouble, and during the Winter months all baskets should

be sterilised in readiness for the coming season. The importation of young plants from other nurseries is a procedure to be deprecated, for it is a fruitful means of disease transmission. Contaminated water from surface wells is a constant source of infection with many diseases, and care should be taken to use a pure water supply. Potatoes and antirrhinums should not be grown in the vicinity of tomatoes as they are susceptible to *Verticillium*.

Disease Resistant Varieties.

The production of resistant varieties has offered the most satisfactory and in some cases the only effective means of controlling a number of plant diseases. We are now attempting to raise a *Verticillium* resistant tomato, bearing in mind the necessity of producing a plant which will yield a good crop of well-formed fruit.

Contaminated Water Supply in Relation to Plant Disease.

It has long been recognised that the elimination of infection centres occupies an important place in the control of all diseases. The quarantine measures employed to combat human diseases provide an excellent example of this, and the success which attends them is sufficient justification for their application. While the intimate relation between polluted water and epidemics of human diseases is now common knowledge but little attention has been given in the past to the corresponding relation between water contaminations and plant diseases. Our attention was drawn to this latter problem by a severe epidemic of "Damping off" in tomato seedlings in 1919 and preliminary experiments showed that the causal organism, *Phytophthora cryptogea*, Pethybridge, was carried by the water used in cultivation. Later in the year the same fact was proved in the case of a severe attack of "Buck-eye Rot" of tomatoes caused by *Phytophthora parasitica*, Dastur. It was evident that a centre of infection existed in the water supply and this appeared of sufficient importance to justify further study. Consequently a large number of nursery water supplies have been examined to ascertain what fungi were present and an attempt has been made to show the relation between the various sources and the extent of contamination.

Experimental.

A reliable method of sampling was devised by filtering large volumes of water and examining the debris collected. The filter, consisting of a layer of cotton wool held in position

between two pieces of wire netting some eight inches square, was wrapped in brown paper and sterilised. To obtain the necessary sample the sterile filter was removed from the paper and secured over the outlet hole of the tank, when the latter was empty. The tank was then filled and approximately 2,000 gallons of water were allowed to pass through the filter. Much of the water passed through the netting beyond the filter: this was necessary to prevent the latter from bending: but sufficient water passed through the cotton wool to yield an adequate supply of fungus spores and bacteria. When the tank was empty the filter was removed, wrapped in a new piece of sterile brown paper and taken to the laboratory, where a careful examination of the debris collected by the cotton wool was made. It is not necessary to give full details of every water supply tested, but representative analyses are shown in Table VII.

A careful examination of the following Table justifies the conclusion that the water supply may be so seriously contaminated as to constitute an important source of infection. It must not be supposed that the species given represent the whole of the fungi present in any single sample. This is not so, for a large number of harmless fungi exist in the water. For the sake of simplicity these have been omitted and only the parasitic organisms tabulated. It will readily be seen that the extent of fungoid contamination of the waters varies with the source from which they are drawn. The purest waters are those drawn from the Water Company's main (Metropolitan Water Board) and deep artesian wells. The few fungi found in these samples were probably nozzle infections, which gained entrance during the taking of the samples and not actual water contaminations. Covered tanks are better than uncovered ones for there is strong evidence that the latter collect fungus spores and become a source of infection for the water passing through. All wells, whether deep or shallow, into which the surface drainage can readily pass yield a large number of species. Wells with faulty brickwork must be placed in this category. It is significant that shallow wells situated some distance away from the glasshouses were purer than those surrounded by houses. Again, those wells whose waters contained a great amount of organic matter were much richer than those of a clearer nature. Water from slow running brooks and ponds were also highly contaminated. The number of fungus species in brook water was reduced by thoroughly clearing away all vegetation and decaying material from the banks. It will readily be seen that the Water Company's water and that drawn from deep artesian wells are comparatively free from fungoid contaminations, while waters from shallow surface wells, ponds

Table VII.

Sources of Water Sample arranged in order of Purity.	Number of samples tested.	No. of times each fungus found in total number of samples.												Average number of fungi per sample.	REMARKS.
		Botrytis cinerea.	Cladosporium cucumerinum.	C. fulvum.	C. herbarum.	Fusarium sp.	Macrosporium solani.	Phytophthora cryptogea.	Ph. parasitica.	Phoma sp.	Rhizoctonia solani.	Rhizopus nigricans.	Verticillium albo-atrum.		
Water Co. Direct from main	4	—	—	—	1	—	—	—	—	4	—	—	—	1.25	These records are more likely to be nozzle contaminations than actual water contaminations.
Water Co. covered tank ...	4	1	—	—	1	—	—	—	—	4	—	—	—	1.50	As above.
Deep artesian well	2	—	—	—	1	1	—	—	—	1	—	—	—	1.50	
Deep well liable to surface contamination	6	—	—	1	6	4	4	—	—	3	3	2	1	4.0	Several wells had faulty brick-work that allowed the entrance of surface drainage.
Water Co. uncovered tank ...	6	4	—	3	6	1	2	—	—	6	—	4	2	4.70	
Brook after cleaning	1	1	—	—	1	1	—	—	—	—	—	1	1	5.0	All vegetation was removed from banks.
Shallow well clear of houses	7	2	—	4	7	7	—	2	2	4	2	7	0	5.30	
Shallow well surrounded by houses	6	4	1	1	6	6	3	2	1	2	3	5	5	6.50	
Shallow well surrounded by houses (high organic content)	2	2	—	—	2	2	1	1	1	2	1	1	2	7.50	
Brook before cleaning ...	1	1	—	—	1	1	1	—	1	—	1	1	1	8.0	
Pond	2	2	—	—	2	2	2	1	1	2	1	2	1	8.0	
Relative frequency of pathogen in Lea Valley waters ...	41	17	1	9	34	25	13	6	6	28	11	23	13	—	

and brooks may be a very serious source of infection. When the various species of *Phytophthora* have been found in water it has been drawn from one of these latter sources.

Isolations.

Representative isolations of the various pathogens were made, grown in pure culture and tested for pathogenicity by performing inoculations. Experiments were carried out to ascertain the extent of growth made by the various fungi in the well waters. To this end, samples of water were obtained, sterilised, and inoculated from pure cultures of the several fungi. In every case growth occurred and was sufficiently strong to show that the fungi can thrive continuously in the waters. There was a striking relation between the rate of growth of the fungi and the amount of decaying organic matter in the water; the rate of growth in the clearer waters being much slower than in the impure waters.

The Purification of Contaminated Waters.

Filtration.

Contaminated water was allowed to percolate through a tightly packed sand and coke filter, some two feet in diameter and six feet in length. The resulting water proved to be free from fungus spores for the first three months during which the filter was in use. After twelve months the efficiency of the filter was slightly reduced, but there was still a great reduction in the number of fungi present in the water after filtration.

Sterilisation by Chemicals.

An attempt was made to determine the toxic action of various chemical compounds upon the vegetative and "summer" spore forms of selected fungi. Comparatively large amounts of mycelium or spores were used and treated with various concentrations of the compounds to ascertain the concentration necessary to kill them. Four fungi were used in the experiments, namely, *Phytophthora cryptogea*, *Phytophthora parasitica*, *Colletotrichum oligochætum* and *Cladosporium fulvum*. The first two fungi produce "Damping off" of tomato seedlings and "Foot rot" of older tomato plants, while the second one produces "Buck-eye" rot of tomato fruit. *Colletotrichum oligochætum* is the cause of "Leaf spot" of the cucumber and *Cladosporium fulvum* the so-called tomato "Mildew." These fungi were selected owing to their comparatively great commercial importance as disease producers.

Sterilisation by Heat.

Spores and mycelium of the various fungi were heated for one minute at various temperatures to determine their death point.

Table VIII.

Showing the lowest concentrations expressed as parts per 100,000 of chemical in the water suspension, which are toxic to the "summer" spore forms of selected fungi (all liquids were measured by volume and solids by weight).

	P. parasitica.	P. cryptogea.	Colletotrichum oligochætum.	Cladosporium fulvum.
	Mycelium and conidia.	Mycelium	Spores.	Spores.
Mercuric chloride ...	20	20	1	2
*"Chloros"	50	50	5	50
Formaldehyde	50	50	70	300
Formic acid	50	50	50	200
Potassium permanganate	100	100	350	400
Copper sulphate... ...	50	40	40	100
Ammonium polysulphide solution 1919 ...	300	200	30	30
Phenol	500	500	200	200
Sulphuric acid	500	300	500	2000
Calcium bisulphite solution	1000	1000	300	300
Potassium sulphide ...	2000	2000	50	200
Acetic acid	200	200	200	300
Ferric chloride	2000	2000	2000	2000
Temperature to which water must be raised to kill mycelium and "summer" spores ...	60°C.	50°C.	60°C.	70°C.

* Proprietary solution.

The results in the above Table show the lowest concentration of each chemical which will kill the vegetative and "summer" spore forms of the fungi used. The compounds are arranged as nearly as possible in order of toxicity; the most efficient ones appearing at the top of the list. It will be seen also that the degree of toxicity varies with the different fungi employed. Mercuric chloride proved to be the most powerful compound tested, followed by "Chloros," formalde-

hyde, formic acid, potassium permanganate, copper sulphate and ammonium polysulphide solution. Of the other compounds tested, sulphuric acid was highly toxic to the mycelium of *P. cryptogea* and potassium sulphide to *Colletotrichum oligochætum*. It must be understood that the concentrations given above are those toxic to the vegetative and thin walled spore forms only of the fungi employed and not to the thick walled resting spores. Thus while they may not completely rid the water of its infections, they practically do so by killing the mycelium and "summer" spores which it contains. Only the thick walled resting spores remain, and these have not been found to any great extent in the water samples tested. By raising the temperature of the water to 70°C., for one minute, the mycelial and "summer" spore forms of the fungi tested were killed. Complete sterilisation of the water is obtained by raising its temperature to boiling point.

Control.

Investigation of the cause and source of any plant disease is not complete unless the water supply has been carefully examined as a possible source of infection, and in cases where it is probable that the water supply is contaminated, steps must be taken to cleanse it.

The first process attempted should be the thorough cleansing of the well, by removing as much algae and decaying plant material as possible, for this makes the water a good medium for fungal growth.

Copper sulphate used at the rate of 10 lbs. to 1,000,000 gallons of water will keep down the growth of algae, which are so objectionable in wells, tanks, etc. For this purpose the copper sulphate may be placed in a bag and suspended in the water. When the water is very thick with particles of decaying plant material it may be cleared by precipitation with alum and sodium carbonate.

When these two latter compounds are mixed aluminium hydroxide or alumina hydrate $Al(OH)_3$ is formed, which being gelatinous, entangles the suspended matter, including fungus spores and bacteria, and carries it down to the bottom of the well. The compounds should be added at the rate of 18 lbs. potash alum and 5 lbs. sodium carbonate for every 25,000 gallons of water which by this means will be cleared in a few hours. Perchloride of Iron at the rate of 9 lbs. per 25,000 gallons of water is also a useful clarifying agent. Of the chemical compounds tested and set out in Table II., mercuric chloride and "Chloros" are the most toxic to fungi. Mercuric chloride, however, is highly poisonous to man, and it is not advisable to use it unless very special precautions are

taken to prevent the workers drinking the treated water. No such restrictions apply to "Chloros." It should be added to the water at the rate of 50 gallons to 100,000 of water, but half that concentration will give protection against the "summer" spore forms of *Phytophthora sp.* Complete sterilisation of the water is obtained by raising its temperature approximately to boiling point. Beneficial results have been obtained by arranging the pipes leading to the tank in such a manner that they are heated by passing through the boiler. The water passing through the pipes is thus thoroughly heated and sterilised.

While it may not be so necessary to supply the more mature plants with disease-free water, it is advisable to sterilise in some way all the water used in the early stages of propagation, when the plants so readily succumb to "Damping off" and "Foot Rot."

In choosing the source of water supply the following points should be considered. Stagnant brooks are really natural sewers, and may be badly contaminated with disease organisms. Ponds full of algae and weeds are suitable breeding places for fungi and bacteria. Shallow surface wells receive surface drainage from the neighbouring land, and are liable to become contaminated, especially if heaps of decaying plants are deposited in their vicinity.

Deep artesian wells are the purest and safest. Care should be taken to cover all wells and tanks to prevent contamination with debris that otherwise may gain entrance.

The valuable assistance of Mr. W. Buddin, M.A., during the summer of 1920 made it possible to undertake this investigation.

Stripe Disease of the Tomato.

During the past year inoculation experiments have been performed upon a number of plants with the bacillus which causes "stripe" disease of the tomato.

These have shown conclusively that the organism from the tomato can cause a number of "stripe" or "streak" diseases of other plants. Positive results have been obtained with the following plants: Sweet pea, garden pea, red clover, broad bean, lucerne, lupin, vetch, sainfoin, and potato. The symptoms of the disease upon these plants bear a strong resemblance to those on the tomato. The lesions are in the form of dry brown or black sunken spots, blotches or furrows.

The knowledge that "streak" disease of the above-mentioned plants and "stripe" disease of the tomato are caused by the same organism is of considerable importance to

commercial growers. It is now possible to explain why certain nurseries have been badly attacked by "stripe" in the first year of their existence: a fact which has hitherto been inexplicable. It is highly probable that the land had previously held a leguminous flora suffering from "streak" disease which had been overlooked. Already we have proved this to be true in a number of nurseries where "stripe" has just started. The previous diseased crop was clover in three cases and vetches in two. It is advisable, therefore, when choosing a site for a new nursery, to have the assistance of an expert, to ascertain if the existing crop is free from "streak" disease.

Report of the Work of the W. B. Randall Assistant.

The object of this investigation is to study the effect of sterilising agents on the organisms of the soil and on the growing plant. The experiments have now been continued since April, 1918, and the results are being written up for publication. Only the practical conclusions and the general results of the laboratory work are given here.

The chemicals tested have been as under:—

1. *Carbolic acid.*—This substance has been thoroughly tested as being the standard material used in the district. It is sometimes applied at the rate of 40 gallons to the house (about $\frac{1}{3}$—$\frac{1}{5}$th acre), but by some growers it is used at double this rate.

There seems no doubt that it increases the yields, even when the control plots are in the neighbourhood of 34 to 36 tons per acre. The results have been in tons per acre:—

Nursery 1.	1917	1918	1919	1920	Average.
House A.					
Control	34.4	39.2	30.0	32.0	33.9
Carbolic	36.8	43.6	35.2	32.5	37.0
Value when control = 100	107	111	117	102	
House B.					
Control		32.3	29.1	26.2	29.2
Carbolic		31.7	33.2	28.0	31.0
Value when control = 100		98	114	107	
Nursery 2.					
Control	27.1	35.0	42.8, 45.0 } 43.9	38.1, 38.7 } 38.4	36.1
Carbolic	30.0	39.0	41.4, 43.9 } 42.7	39.4, 40.0 } 39.7	37.9
Value when control = 100	111	112	97	103	

In these cases the dressing was at the rate of 80 gallons to the house ($\frac{1}{9}$ gallon per square yard).

The yields on the untreated plots are good, without being extraordinary. There is no serious disease, though the plants are not entirely free from disease. It is difficult to account for the variations in effectiveness in the different seasons. The same plots are treated year after year. It is impossible to say whether the returns are falling off, but it seems clear that the average yield cannot readily be pushed beyond 40 tons per acre, and carbolic is therefore without action when the control is up to this figure. In some seasons the plants on the treated plots have been rather too rank.

Experiments were tried at the Harpenden Nurseries with heavier doses. These did not prove useful. Further, an attempt was made to apply the carbolic acid on sand instead of watering it in (the usual custom), but this also did not improve the crop. The results were:—

Gallons per house.	As per cent.	How applied.	Early pickings Control = 100.	Total crop Control = 100.
80	.25	Water	101	105
			104	95
		Sand	82	85
40	.125	Water		97
				86
		Sand		95

Much more striking effects were produced in Nursery 3 where prior to the experiment the house had been a failure. The results were:—

Season 1920.

	June, lbs. per plot.
Control	38.7
Carbolic acid	45.1
Value when control = 100	117

This shows a greater improvement and indicates that carbolic acid is most likely to be effective where the crop yield is low.

Laboratory experiments show that carbolic acid has little harmful effect on fungi or on wireworms: it reduces club if applied in Autumn, but not so surely if used in Spring. The

reason for its failure with wireworms, fungi, and under certain circumstances, club, is probably to be found in the fact that it rapidly disappears from the soil, even when applied at the 80 gallon per house (M 50) dose, being consumed by some of the soil bacteria which multiply to astonishing numbers in its presence. In consequence of this it is not surprising to find that it has no beneficial effect in its second year, nor does it appear to injure the soil by repeated use. Unlike steam, it does not lead to rankness of growth.

The effect of repeating the dressings of carbolic is shown in Nursery 1, House A.

2. *Formaldehyde.*—This substance has proved of value in reducing the activity of soil fungi: it has given clean roots where the untreated roots were brown with fungus attack. It does not, however, readily attack *Heterodera* (the "club" eelworm) and it seems to have no power of increasing bacterial activity in the soil such as carbolic acid possesses. However, its action against fungi is so valuable that it has been well tested. The crops in tons per acre were:—

Nursery 1.	1917	1918	1919	1920	Average.
House A.					
Control	34.4	39.2	30.0	32.0	33.9
Formaldehyde	35.6	41.5	35.5	33.0	36.4
Value when control = 100	103	106	118	103	
House B.					
Control		32.3	29.1	26.2	29.2
Formaldehyde		38.4	34.2	26.2	32.9

One-ninth gallon was applied per square yard, *i.e.*, 67 gallons per house.

Its action has been very marked, however, in Nursery 3, where the control plot gave such poor results.

	June, lbs. per plot
Control	38.7
Formaldehyde	45.2
Value when control = 100	117

3. *Sodium cyanide.*- This substance has been largely recommended in America, and if effective it could be obtained in quantity. Laboratory experiments show that it stimulates bacterial activity and somewhat reduces fungi. When applied to soil in Autumn at the rate of 0-1% (M 50 or 1 ton per acre) it killed most of the *Heterodera* "club." It was not, however, particularly effective in Spring applications.

Its action on the plant varies with the conditions. At Harpenden even 1 ton to the acre proved harmless, but in Nursery No. 3 (Waltham Cross) it injured the plants, turning them black in the crown and reducing the crop to 1½ lbs. per plant.

4. *Dichlorcresol.*—Many experiments indicate that chlorination greatly increases the effectiveness of carbolic acid: the resulting product (dichlorcresol) is so potent that only 10 gallons would be needed in place of the 40 gallons used at present. It persists longer in the soil so that its range of action is increased: instead of disappearing in a few days it remains for weeks, or even months. Unless used in sufficiently small quantity and properly watered in it is liable to injure plants. But its potency is considerable. Even in very small doses (M 100) it greatly reduces eelworm and fungi, in which respect it differs from carbolic acid. The vegetation experiments have not yet been quite satisfactory as the material has been used in too strong a dose, viz., at the same strength as carbolic (40 gallons per house): we now know that only one fourth of this quantity should have been used. At Nursery No. 4 the June pickings were down 7% in consequence; though by the end of the Summer all four plots had recovered and gave increases varying from 8% to 33%, average 18%, over the control plots. The results at Harpenden were:—

Strength.	Equivalent to Carbolic per house.	June pickings.	Final fruit.	Remarks.
0.25%	80 gallons	Depressed 15%	Depressed 9%	Too strong
0.125%	40 „	Depressed 4% Raised 8%	Raised 1% „ 4%	Still too strong
0.05%	16 „	Depressed 8%	„ 8%	Little too strong

It is proposed to make further experiments using the 0.05% dose as the strongest.

5. *Chlorpicrin.*—This material proved of interest because it was obtainable in quantity after the Armistice. It was injected into the soil without difficulty by means of a Vermorel injector at the rate of 0.05% (M 300), *i.e.*, 10 cwts. per acre, equal to about 16 gallons carbolic per house. It remained in the soil for a long time and proved fatal to *Heterodera* (root knot or eelworm). But it seems to have had no adverse effect on fungi, nor does it stimulate the bacterial growth.

In Nursery 4 and in pots the effect was beneficial: in the nursery the gain in fruit was 26% on the whole season, though there was a fall of 6% in the June pickings: in pots the gain was 60% and there was a remarkable stimulation of root growth. In the Harpenden nurseries, however, it was without action, neither the 0.05% nor the 0.03% having any effect.

6. *Nitrobenzene.*—This substance is not particularly promising. It somewhat reduces fungi and eelworm and stimulates bacterial action; but it led to no improvement in crop, and it would need to be applied in large quantities to be effective.

As in the case of carbolic acid, however, its action is much intensified by chlorination.

7. *Chlordinitrobenzene.*—This is the most potent substance we have yet found. In very small quantities corresponding to 16 gallons carbolic per house it profoundly cut down fungi and root-knot eelworm, but at the same time stimulated bacterial growth. Even this small amount, however, proved too strong, and probably half or a quarter the dressing would have been safer. At the moment the substance is of no practical interest, but it would form a basis for the manufacture of a potent soil steriliser if carbolic acid rose to too high a price.

8. *Picric acid.*—This was tested because it was available in quantity after the Armistice. It is a potent steriliser, readily cutting down eelworm and fungi, but it has a harmful effect on the plant unless used in quite small quantities. In pot experiments it appeared that the nitrogen became available in the soil. It might be worth following up if the preceeding substances should for any reason not be available.

9. *Sulgene.*—A substance prepared by M. Truffaut and used in France, gave at Nursery No. 4 a substantial increase of no less than 26% over the control plot. It did not, however, appear to diminish the "club."

10. *Lime.*—This appears to improve the crop at the Harpenden nurseries, and in Nursery No. 4, though it proved ineffective at Nurseries 1 and 2. It is not particularly potent against club or fungi, even when used at the rate of 10 tons to the acre. Its action is variable and no doubt complex.

11 & 12. *Thiocyanates of Sodium and Potassium.*—These proved useless against "club," but they increased the crops in Nursery 4. They do not appear at the moment to be promising.

13. *Naphthalene.*—This is ineffective. It disappears too rapidly from the soil, being apparently decomposed by some of the soil organisms. While it lasts it drives off wireworms.

14. *Calcium sulphide and Naphthalene.*—Calcium sulphide was added to see if it would stabilise the Naphthalene, but it failed to do so. The mixture was without effect on fungi and eelworm, and while it stimulated bacterial activity, it did not increase the yield of fruit.

Steam and Hot Water.

These are put last because they form the standards against which the others are measured. They are effective against club and some fungi, and generally conduce to good healthy growth. Indeed the growth is sometimes too good and appears to be detrimental to fruiting: the steamed plots have in rather more than half the tests come out inferior to those treated with carbolic acid. The figures are in tons per acre:—

Nursery 1.

	House A.				House B.		
	1917	1918	1919	1920	1918	1919	1920
Control ...	34.4	39.2	30.0	32.0	32.3	29.1	25.3
Steam ...	32.5	39.2	34.9	32.2	40.0	37.1	30.4
Carbolic acid..	36.8	43.6	35.2	35.8 29.2	31.7	33.2	28.0

In Nursery 2 the figures are:—

Control ...	27.1	35.0	42.8	38.1	45.0	38.7
Steam ...	34.0	38.1	44.0	38.2	42.5	34.8
Hot water ...	26.1	37.9	44.8	41.4	42.2	40.4
Carbolic acid..	30.0	39.0	41.4	39.4	43.9	40.0

This conclusion is quite hopeful because as the preceding paragraphs show there is evidence that we can improve on carbolic acid.

Nursery No. 4.

Yield of tomatoes from Nursery No. 4. At this house (250 ft. by 30 ft.) half was treated in autumn (December, 1915) and half in spring (February 27th, 1920). Soil dug over, not trenched.

Autumn Treated.

	Lbs. per plot.
Carbolic acid (on sand)	46.0
Formaldehyde	44.2
Carbolic acid (in water)	44.2
M. Truffaut's Sulgene	43.7
Lime .5%	41.5
CONTROL	38.7
Sodium thiocyanate	38.0
Chlorpicrin	37.0
Calcium sulphide plus Naphthalene	36.0
Dichlorcresol (on sand)	36.0
Dichlorcresol (in water)	35.5
Potassium thiocyanate	34.5
Lime 1%	31.0
Sodium cyanide	4.2

Spring Treated.

	Lbs. per plot.
Lime .5%	48.5
Carbolic acid (in water)	47.2
Formaldehyde	46.2
Dichlorcresol (in water)	45.0
CONTROL	44.3
Carbolic acid (on sand)	42.5
Lime	42.5
Calcium sulphide plus Naphthalene	41.3
Potassium thiocyanate	40.0
M. Truffaut's Sulgene	39.8
Sodium thiocyanate	36.0
Chlorpicrin	32.5
Lime 1%	31.0
Sodium cyanide	30.0
Dichlorcresol (on sand)	29.0

Relative Values.

Autumn Treated.

Carbolic acid (on sand)	150
Carbolic acid (in water)	148
Formaldehyde	137½
Dichlorcresol (on sand)	133
0.5% Lime	133½
M. Truffaut's Sulgene	132
Chlorpicrin	129½
Potassium thiocyanate	126
1% Lime	123½
Calcium sulphide plus naphthalene	118
Sodium thiocyanate	117
Dichlorcresol (in water)	113½
CONTROL	99
Sodium cyanide	65

Spring Treated.

0.5% Lime	149
0.25% Carbolic acid (on sand)	147½
0.25% „ „ (in water)	147
Formaldehyde	140½
Chlorpicrin	135
M. Truffaut's Sulgene	132
Calcium sulphide plus naphthalene	131
Dichlorcresol (on sand)	129½
Potassium thiocyanate	128½
Sodium thiocyanate	128½
1% Lime	127½
Sodium cyanide	119½
Dichlorcresol (in water)	118½
CONTROL	109

It will be observed that chlorpicrin which caused the roots to be free from eelworm gave a smaller crop than the badly clubbed plants from plots treated with carbolic acid, formaldehyde, 0.5% lime or dichlorcresol. In general autumn treatment applied before the soil had cooled proved more effective against eelworm than spring treatment applied before it had warmed.

Lea Valley Report.

General Introduction.

The industry with which the Experimental Station deals, is concerned almost exclusively with the production under glass of tomatoes and cucumbers. It began some 40 years ago and increased rapidly up to the time of the War; it has now grown to enormous dimensions and has become one of the most important branches of British Horticulture. Tomatoes and cucumbers are now popular articles of food in cities and industrial regions, and there can be no doubt of their high dietetic value. The method of cultivation has developed; yields of 30 tons of tomatoes per acre are not uncommon, and considerably higher figures are recorded; 80 tons of cucumbers per acre are not unusually obtained. No crops grown on farm for human food begin to approach these values per acre, and it can confidently be said that the industry makes a highly important contribution to the Nation's food supply. If by any calamity the industry were swept away, or if as might easily happen, its crops were badly damaged by disease, the health of the workers would assuredly suffer.

As might be expected the industry is highly specialised and it is a great tribute to the growers that, in spite of many difficulties, they have developed it to its present standard of efficiency. The houses are all close together and the conditions are favourable to disease. There are special soil problems of considerable intricacy, and the manuring is carried out on lines completely different from those generally adopted in horticulture and agriculture.

The Station arose out of the recognition of these special difficulties. In the first instance some experiments were arranged by the Rothamsted Experimental Station at the suggestion of Mr. W. B. Randall in 1910. Soil sickness was then causing trouble in the nurseries and some of the Rothamsted work indicated the way in which it could in certain cases be controlled. Sick soil was sent over by Mr. Randall to Rothamsted and experiments were carried out during the season 1911, followed by demonstrations in the Lea Valley district, which proved of interest to growers. It was felt however that much more satisfactory results could be obtained if investigations could be made on the spot and the only practicable way of doing this was to set up an Experimental Station. The idea was vigorously supported by Messrs. H. O. Larsen, C. H. Shoults and others, and as a result of deputations to the County Councils and the Ministry of Agriculture, financial support was promised if the growers were prepared to do their part in

maintaining the Station. This the growers undertook and the Station was set up in 1914, its first report being issued in 1915.

The investigations so far carried out have dealt with the management and manuring of the tomato and cucumber crops, and with the diseases and pests from which they suffer. It was anticipated that the special conditions of tomato and cucumber houses would cause considerable variation from the ordinary horticultural and agricultural experience. The results have shown that this is the case: so specialised is the industry that the manuring and management of the two staple crops must form the subject of investigations for some years to come.

Disease and pests are unfortunately permanent accompaniments of the industry and new ones are perpetually liable to turn up. Experience at the Station shows that loss by disease is one of the most serious risks in the industry. Growers who keep accurate accounts have produced figures which at first sight seem astounding, showing how much more they might have gained had their crops been free from disease. It is of course too much to hope that any crops grown under the conditions of the Lea Valley could ever be free from risk of attack of insect and fungus pests, but the work of the Station has shown how some of these pests can be controlled, and growers who take the precautions and remedial measures indicated can escape losses which they would otherwise suffer.

The results of the experiments with cucumbers.

The common practice of the district is to grow cucumbers on a border made up of loam and straw manure, but there is some disagreement as to the proportions, some growers using equal parts; others preferring two of loam to one of manure. The temperature and moisture conditions of the house being high the plant makes very rapid growth and under favourable conditions gives heavy crops of fruit. Naturally the manuring must be heavy. The experiments show that the effect of the dung varies considerably. In seasons when the spring is cold dung has a great effect, giving no less than 14 to 30% increases: when however the spring is warm its effect is much less, the increase being as low as 2 to 4% only. This observation suggests that the dung owes part of its beneficial effect to the warming of the soil: if so it could be largely dispensed with should any cheaper and equally effective method of warming be devised.

It is the invariable custom to add top-dressings of manure at frequent intervals to the borders of dung and loam, but the experiments show that the results do not always justify this practice. Crushed hoofs and bone meal are commonly used, but at the Station they gave no increases in crop whether they were applied alone or in combination; bone meal indeed in

some cases proved slightly harmful. Artificial fertilisers must also be used with caution. Neither potash nor nitrogenous fertilisers increased the crop; on the contrary they appeared to be rather harmful. Superphosphate on the other hand appears to have a beneficial effect. This observation suggests that the extraordinarily heavy dressing of dung gives the crop all the nitrogen and potash it requires, but not sufficient phosphate. When the balance is re-dressed by adding superphosphate the crop responds by better growth. So long, therefore, as growers use the ordinary proportions of dung for making their borders they need not use nitrogenous or potassic manures in their top dressings, *unless they know from experience that the conditions in their particular houses require these substances*, but could confine themselves to superphosphate.

It is recognised that stable manure will probably become more and more difficult to obtain as the horses in London become displaced by motors. Experiments are, therefore, in hand to find out how economies in the use of dung may be effected. The work is rendered slow and tedious by the fact that position in the house makes much more difference to the crop than any addition or omission of manure; and in view of the magnitude of the financial interest in the crop it is essential that no wrong advice should be given.

Results of the experiments with tomatoes.

Tomatoes are grown in the actual soil covered by the house and not in artificial borders, such as those used for cucumbers. The temperature and water supply are both kept much lower, the rate of growth is less and the crop is smaller than in the case of cucumbers. Nevertheless the conditions are still far removed from those of outdoor market gardening and the results of the experiments were in some respects unexpected.

The first great point to settle was whether it was better to push on the plant by conserving the sun's heat in the house during June (which is done by closing down the ventilators), or to obtain a slower more natural growth by keeping down the temperature by allowing more ventilation. The results show that forced growth gives a higher yield of fruit in June and less in July than the slower growth, but the total yield over the whole season is not appreciably affected. The advisability of forcing, therefore, depends on the prevailing prices: at present these are considerably higher in June than in July.

The manuring of tomatoes has proved of considerable interest. Growers know by experience that too rank a growth is undesirable and tends to prevent "setting." There seems

little doubt that this view is correct: there is apparently an antagonism between growth and fruiting which is seen also in other cases. Unfortunately this antagonism complicates the management of the crop a good deal, and it means that the grower must aim at some kind of compromise: he must secure sufficient leaf, but not too much. Manuring, therefore, is not easily reduced to rule. It seems clear, however, that potash is beneficial, improving the yield of fruit and increasing the health and vigour of the plant, and so enabling it to resist disease attacks. Phosphates are less necessary. Where the soil is nearly virgin turf nitrogenous manures did actual harm and reduced the crop. As the soil becomes older it is possible that the need for nitrogen may become greater, and also when the plants are grown in pots.

There remains, however, a great deal of work to be done before the precise conditions causing increase in fruit yield will be known. It is possible to control almost to a nicety the yield of leaf in a large number of crops, but there is still much to learn about fruiting. Many growers consider that the conditions of virgin turf are favourable to large crops of fruit, but that the yields deteriorate as cultivation continues. It is possible that the virgin turf contains or produces something specially favourable to fruiting, and when the supplies are exhausted fruit yields fall. This possibility is being investigated.

As in the case of cucumbers position in the house has a more important effect on fruit yields than manuring. Striking results are given in the 4th and 5th Reports. It may be that aeration is an important factor and experiments are in hand to test this possibility.

The diseases and pests investigated are fully dealt with in the special reports of the Entomologist, the Mycologist, and the W. B. Randall Assistant. The Entomologist has studied the following and suggested practicable remedies:—

I.—Tomato Moth.

II.—White Fly.

The Mycologist has studied:—

I.—"Damping-off" and "Foot-rot" of Tomatoes.

II.—Stripe Disease of Tomatoes.

III.—Sleepy Disease of Tomatoes.

IV.—Relation of Contaminated Water Supply to Fungous Diseases.

The W. B. Randall Assistant has gone fully into the possibility of finding efficient substitutes for carbolic acid, which on account of its popularity is now rising in price. Some useful lines have been opened up, but it is shown that no one substance will deal with all soil troubles, but that the grower will need a choice of two or three materials to suit the particular disease from which he is suffering.

Cucumbers. Summary, 1916-1920.

Manurial Experiments with Cucumbers.

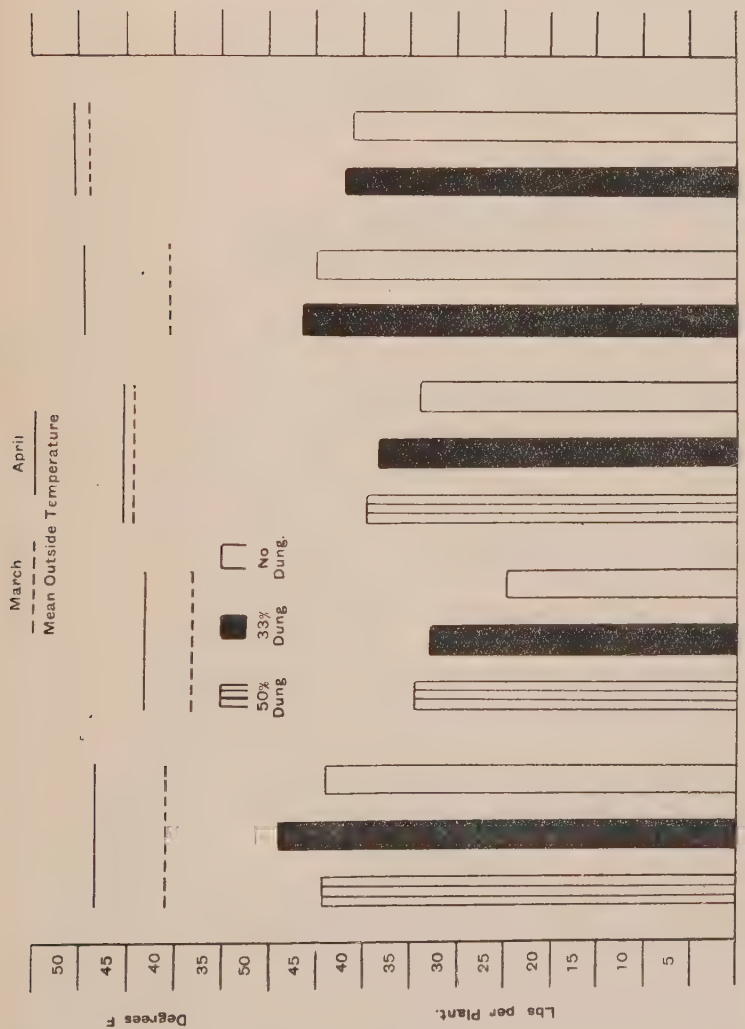
Experiments intended to discover the manurial requirements of cucumbers have been continued for five years and are still in progress. Borders have been made up with loam alone and with loam in combination with various proportions of dung, from 33% to 66%. To the borders containing dung organic and artifical manures have been added and the resulting crops have been contrasted with those given by loam and dung alone. Whether these organic and artificial manures may be substituted for the dung has also been investigated. With one exception in 1920 the top dressings were always of the same composition as the original borders. Lime has always been included in the border at the rate of 1lb. to the yard run and in the top-dressings at the rate of 1lb. to the barrowful, *i.e.*, 1lb. in 60lbs. of compost in each case. For the proportions of fertilisers reference should be made to the Annual Reports of the Station.

Importance of Dung.

The presence of dung in the border is an undoubted advantage and in each year the borders which contained it gave better results than those with loam alone, as the following table shows (Table I.). These figures show that a border half loam, half dung cannot be relied upon to do better than one composed of one part of dung to two parts of loam so the latter must be considered the more economical. The increase in the crop given by the addition of dung varies greatly in the different years and the variation bears so close a relation to the character of the Spring that it cannot be accidental. 1917 had a very cold Spring and 33% dung in the border gave an increased crop of 35.5%, and 50% dung an increase of 40% as compared with loam alone. 1920 had a very warm Spring and the increase was only 2%. The other years were intermediate in character between these and the increases given by 33% dung were also intermediate: 1916, cold March and warm

April, 11% increase; 1918, moderate March and cool April, 14% increase; 1919, cold March and cool April, 4% increase. These facts are shown graphically in Figure 1 in which the mean

Figure 1.



outside temperatures for March and April, the first two months after planting out, are included. The correspondence of the increases to the temperatures of April is particularly striking.

Table I.,

showing the Varying Advantage in the Addition of Dung.

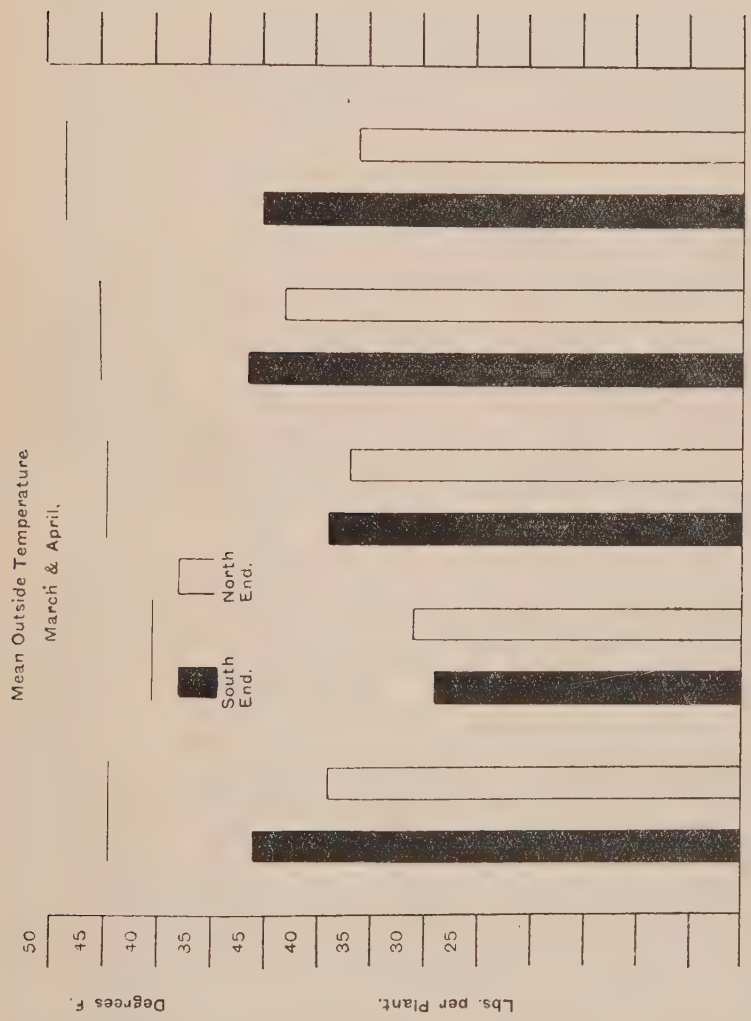
		Average Yield in Pounds per Plant in 1916	1917	1918	1919	1920
Loam alone...	...	44.0	24.8	33.9	44.9	41.0
With 33% dung	...	48.9	33.1	38.7	46.5	41.9
With 50% dung	...	44.3	34.6	39.8	—	—
Mean outside Temperatures	March	41.4°	37.4°	43.0°	39.7°	45.7°
	April	48.7°	41.8°	44.3°	45.2°	48.1°

This confirms the suggestion made in the Third Annual Report that the advantage given by adding dung is largely physical leading to a more open soil and a warmer border while the manure is disintegrating. The advantage of the warmth would naturally be greater in the colder Springs.

Seasonal Effects.

The cold Spring of 1917 was followed by a favourable year from May onwards as the Meteorological Records show but the crop obtained was the very low one of 31lbs. of fruit per plant, and another fact indicates that this was due to chill in the early months. The cucumber houses D—F are so placed that the North end is overshadowed to the East by the Laboratory and a glass corridor which is ten feet high. These cut off the morning sun from the plots at this end and the plot D1 nearest to the Laboratory has always given the lowest yield in the block, with one exception when it ranked 21st in 22 plots, while an examination of the returns from the plots in Houses E and F at this end shows that the effect of the shadow is distinct in E but is almost negligible in F. The North end is near the boilers and the temperature records show that it is on the average from 2—4° F warmer than the South end. The yield from the North end of the block has been less in each year than at the South end, with the exception of 1917 when the plants at the latter averaged 29lbs. of fruit and those at the former averaged 31 lbs. (see Figure 2). Clearly the chill in the Spring of 1917 affected the plants at the South end more than at the North end and counterbalanced the harmful effect of the shadow. This point may seem trivial to cucumber growers in general as merely concerning a single block of houses but it has been treated at some length because it emphasizes the importance of protecting the plants from chill at the beginning of the growing season and it is additional evidence supporting what has been already said about the dung in the border, that its value lies in warming rather than in feeding the plant.

Figure 2.



Can other fertilisers replace dung?

No combination of other fertilisers imparts to soil the physical effects of dung, so that it is not surprising to find that the various combinations of these substances in beds of loam have given almost uniformly lower crop yields than loam and dung alone. In the tables (Table II.) are shown 18 cases where crops obtained with these treatments are contrasted with loam plus 33% dung, and in 14 of these a reduction in crop resulted.

Table II.

Showing the Average Yield of Cucumbers (expressed in pounds per plant) given by various Manurial Treatments. Any result may be compared with any other of the same year with the exception of those enclosed in brackets which are known to be small on account of the position of the plot.

	1916.			1917.			1918.		
Proportion of dung	0	33%	50%	0	33%	50%	0	33%	50%
No added fertiliser (1)		47.4	46.7	(21.3)	38.0	34.6	(28.5)	40.3	(40.5)
,, ,, ,, (2)	0	0	0	24.1	29.9	31.7	36.0	41.0	40.6
Added crushed hoofs	0	49.7	46.5	25.6	35.1	37.9	32.3	38.9	39 7
Added crushed hoofs and bone meal	44.0	50.0	45.0	26.0	32.1	37.1	35.6	36.5	39.3
Added bone meal (1)	0	48.3	(39.2)	27.4	30.2	35.7	(33.9)	36.5	(39.1)
,, ,, ,, (2)	0	0	0	24.3	33.5	30.5	37.4	39.1	39.7

	1919.		1920.	
Proportion of dung	0	33%	0	33%
No added fertiliser (1)	(38.3)	(35.8)	(35.6)	(33 6)
,, ,, ,, (2)	45.3	47.2	44.8	46.5
,, ,, ,, (3)	(40.6)	(45.0)	(33.0)	(38.7)
,, ,, ,, (4)	44.1	45.4	44.8	47.9
Added complete artificials	45.4	49.6	43.1	43.2
Added superphosphate and ammonium nitrate	48.7	51.1	41.2	44.6
Added sulphate of potash and ammonium nitrate	50.2	47.2	42.2	40.3
Added superphosphate and sulphate of potash	46.6	51.9	46.3	43.7

The remaining four occurred in 1919 and 1920 when the increase given by dung was slight, and in one of these cases the advantage was negligible being only .6% and in the remaining three it was 5%, 5% and 8% respectively. As these values are counterbalanced by reverse results from the same treatments we may dismiss them as accidental. This being the case there is no useful purpose to be served by discussing whether any fertilisers other than dung added to loam give a better result than loam alone as dung if available will always be employed in the border. It becomes a technical question of interest mainly to the specialist in manures.

Can the ordinary compost of loam and dung be improved?

There remains the important point as to whether the compost of loam and dung may be improved by the addition of other ingredients. It must be remembered that the manurial treatment of the cucumber as it is grown in hot-houses is probably unique. It is planted in a rich bed and within a month it receives a top dressing of rich loam and dung, which is repeated frequently. Experienced growers know well that the cucumber must have an extensive and vigorous root-system, and liberal top dressings are added not

because the food in the original bed is used up, but because in most cases the roots in it die and rot off. Unless fresh compost is supplied for the new roots the plant becomes exhausted. This being the case it is not surprising to find that crushed hoofs and bone meal have not increased the crops as these substances must be broken down by organisms in the soil before the plant can absorb them.

In six cases crushed hoofs have been added and in three of these the crop was greater than that given by loam and dung alone, and in three cases it was less. In six cases hoofs and bone meal were added and in two cases the yield was greater than with loam and dung alone, and in four cases it was less. In eight cases bone meal was added and in two cases the crop was greater than with loam and dung alone, and in six cases it was less. (See Table II.) It would appear from this that in the presence of dung the addition of hoofs has no effect one way or the other, but that the addition of bone meal may be actually harmful. Any harmful effect it may have, however, cannot be due to its phosphatic contents in view of the results obtained with other phosphatic manures.

In other experiments artificial fertilisers have been added to the border of loam and dung in such a condition that the plant can at once absorb them. Superphosphate, sulphate of potash and ammonium nitrate, called "complete artificials," and combinations of two of these with the third component omitted, have been added to the borders containing 33% dung in the following proportions, the quantities given being those employed in a 24 foot run of border.

Table III.,

Showing the Quantities of Artificials used in Houses D and E to the 24 foot run of border.*

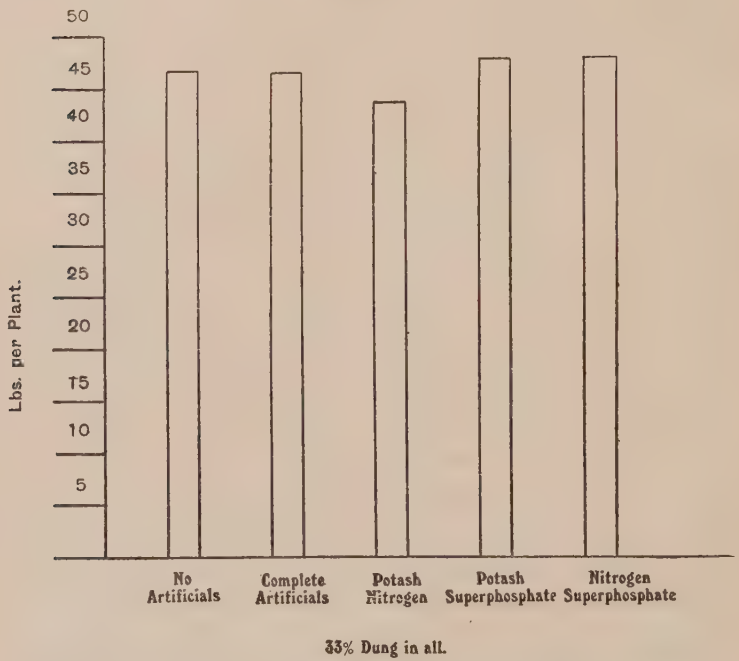
	Original border	First ten top dressings	Second ten top dressings
Superphosphate	2½ lbs.	8½ ozs.	13 ozs.
Sulphate of potash ...	1 lb.	3 ozs.	5 ozs.
Ammonium nitrate ...	1½ lbs.	6 ozs.	9 ozs.

* The border is built up with an 18 inch base on the soil of the house at the rate of 20 lbs. of compost to the foot length.

In 1919 in each case the resulting crop was apparently improved, but in 1920 exactly the reverse was the case, so the experiment in all its details is being repeated in the present year. Dr. E. J. Russell has drawn attention to an interesting point in this series. In each year the border containing ammonium nitrate and potash without phosphate gave the lowest result of the four, and in each case the complete artificials gave the next lowest. This seems to show that potash and nitrogen in the presence of dung have a depressing

effect on the crop which the amount of superphosphate used exactly counterbalances. It is exceedingly curious that if the average results of the two years are considered, the use of complete artificials with dung gives almost the same result as loam and dung alone (46.4 and 46.7 lbs. per plant); nitrate and potash in combination resulted in a decrease of 2.7 lbs. per plant; nitrate with superphosphate gave an increase of 1.4 lbs. and potash with superphosphate gave just the same increase of 1.4 lbs. (Figure 3.)

Figure 3.



Superphosphate alone should thus be a useful addition to loam and dung, and in the one other experiment which bears upon this point, this was the case. In 1917, borders were made up of two parts of dung to one part of loam and the house was divided into six plots, in two of which no phosphate was added, while in two bone meal was used, in one superphosphate, and in one basic slag. The average crop without phosphates was 26.6 lbs. per plant, with bone meal added it was lower, 25 lbs. per plant, with basic slag, 28.8 lbs., while superphosphate gave the best result of 30.4 lbs. (It should be remembered that this was the year in which all the yields were low.)

Complete artificials in top dressings only.

In all the cases so far discussed the composition of each particular border and its top dressing has been much the same. In 1920 an experiment was begun in which House F was divided into six plots, two having a border of loam and dung, and top dressings of the same; four had an original border of loam only and, while two of these received top dressings of loam alone, the other two received, in each top dressing, superphosphate 11½ ozs., potash 4 ozs., ammonium nitrate 8 ozs. to each 32 feet of border. The resulting crops in lbs. per plant were as follows:—loam + dung, 40.2; loam only, 39.7; loam + artificials, 39.2. The artificials did not increase the crop.

Conclusions.

The conclusions to which these experiments point are that when cucumbers receive a frequent top dressing of good loam they need no further feeding, but that the addition of 33% dung is an advantage owing to its physical effects which have more influence in cold seasons. The addition of superphosphate to the loam and dung seems to be an advantage, probably as balancing the nitrogen in the dung.

These conclusions will be tested further. One of the houses will be divided into four beds, all of which will be made up of two parts loam and one part dung, and top dressings of the same composition will be given to all until the end of April, or later should May prove a cold month. After this two of the beds will receive top dressings of loam only and two will be given loam and dung. It should prove of benefit to cucumber growers if it can be shown that dung may be withheld from the border at the end of the cold weather as this manure becomes steadily more difficult to obtain.

Superphosphate as the sole additional fertiliser will be added in the borders and top dressings of one of each pair of beds.

Tomatoes. Summary, 1916-1920.

Damping Experiment.

This experiment was begun in 1916 for the purpose of determining the effect of regular overhead damping upon the setting of the fruit and was continued for a period of four years. Four varieties of tomatoes were grown and compared with a corresponding number of the same varieties in the next house, which was not damped overhead. The damping was done about 10 a.m. each day, and in order not to introduce any error due to the mechanical shaking of the plants while

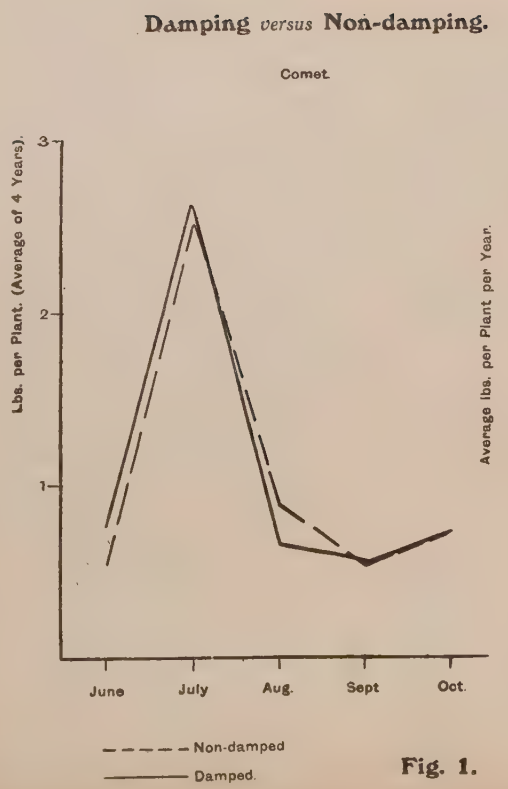

Damping versus Non-damping.
Comet.
Lbs. per Plant. (Average of 4 Years).
3
2
1
June
July
Aug.
Sept
Oct.
Non-damped
Damped.
Average lbs. per Plant per Year.
5
4
3
2
1
Damped
Non-damped.

Fig. 1.

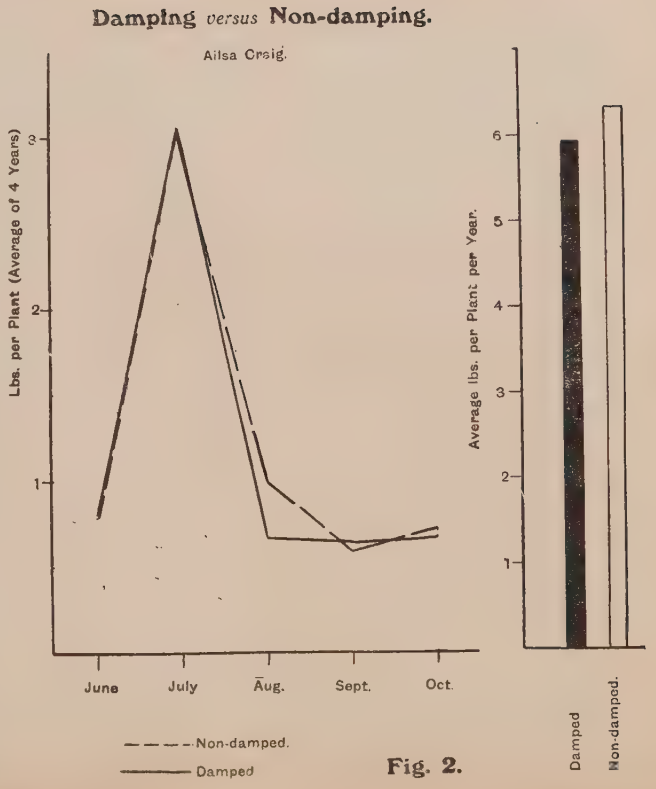

Damping versus Non-damping.
Ailsa Craig.
Lbs. per Plant (Average of 4 Years)
3
2
1
June
July
Aug.
Sept.
Oct.
Non-damped.
Damped
Average lbs. per Plant per Year.
6
5
4
3
2
1
Damped
Non-damped.

Fig. 2.

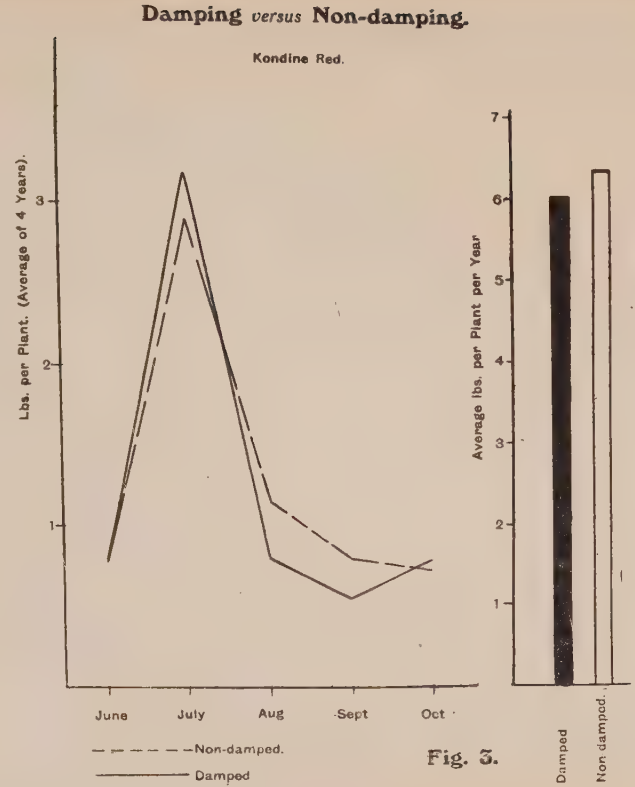

Damping versus Non-damping.
Kondine Red.
Lbs. per Plant. (Average of 4 Years).
1
2
3
June
July
Aug
Sept
Oct
Non-damped.
Damped
Average lbs. per Plant per Year
1
2
3
4
5
6
7
Damped
Non dampod.

Fig. 3.

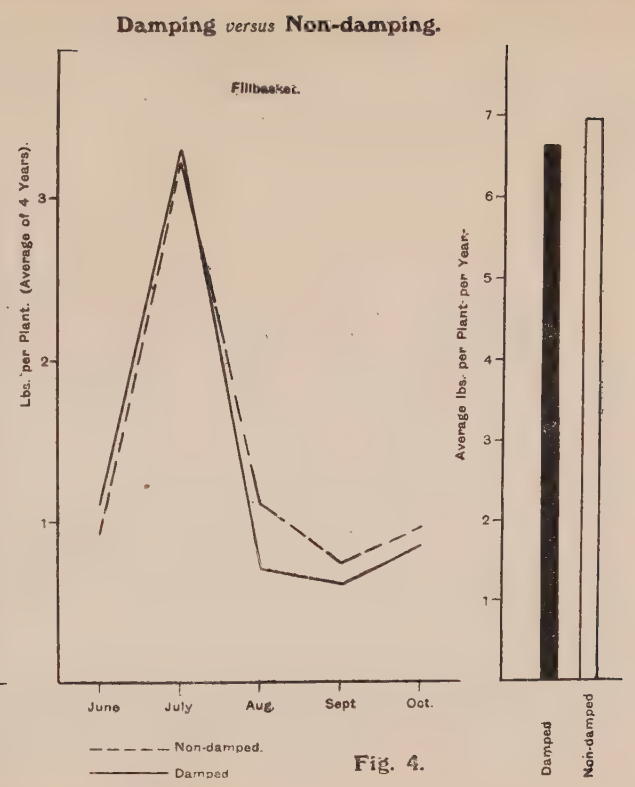

Damping versus Non-damping.
Fillbasket.
Lbs. per Plant. (Average of 4 Years).
1
2
3
June
July
Aug
Sept
Oct.
Non-damped.
Damped
Average lbs. per Plant per Year.
1
2
3
4
5
6
7
Damped
Non-damped

Fig. 4.

spraying, the plants in the non-damped house were slightly shaken at the same time each day. The manurial treatment was identical in each house. The following graphs and diagrams (Figs. 1—4) represent the result of the four years' experimentation, each variety being treated separately. The graphs show the average yield for each month in pounds per plant, the continuous line representing the yield from the damped plants and the dotted line that from the non-damped plants. In the diagrams the black column represents the average yearly yield in pounds per plant from the damped plants, and the white column that from the non-damped plants.

The results obtained with Fillbasket, Kondine Red and Ailsa Craig show that the total yield obtained by the damping is slightly less than without damping. Comet, however, gives practically identical total yields with each treatment.

Striking differences in yield are shown by the different varieties. Fillbasket shows the highest, Kondine Red and Ailsa Craig an intermediate, and Comet the lowest average yearly yield.

Some small differences are seen in the monthly results; Comet and Fillbasket show a slight increase in the yield for June and July, Kondine Red a slight increase for July, Fillbasket and Kondine Red a decrease for August and September, and Ailsa Craig and Comet a decrease for August as the result of damping. The general conclusion is that only in case of Comet and Fillbasket is there any gain by damping and then it is only very slight.

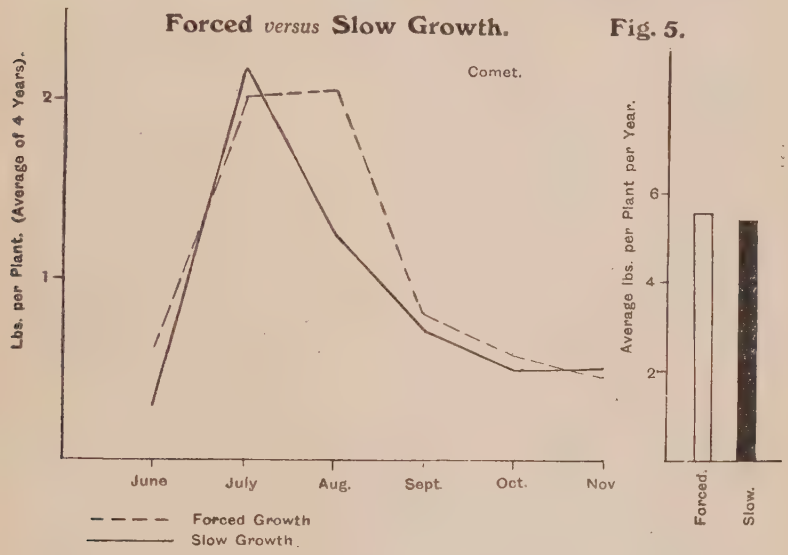
Slow versus Forced Growth of Tomatoes.

In 1917 an experiment was commenced, and continued for four years, to determine if it was possible to obtain an earlier and more valuable crop by "bottling-up" or taking fuller advantage of the sun's heat. During the first three years the experiment was performed in the Isolation House; forced growth being carried out in one and slow growth in the other of the two chambers into which the house was already divided.

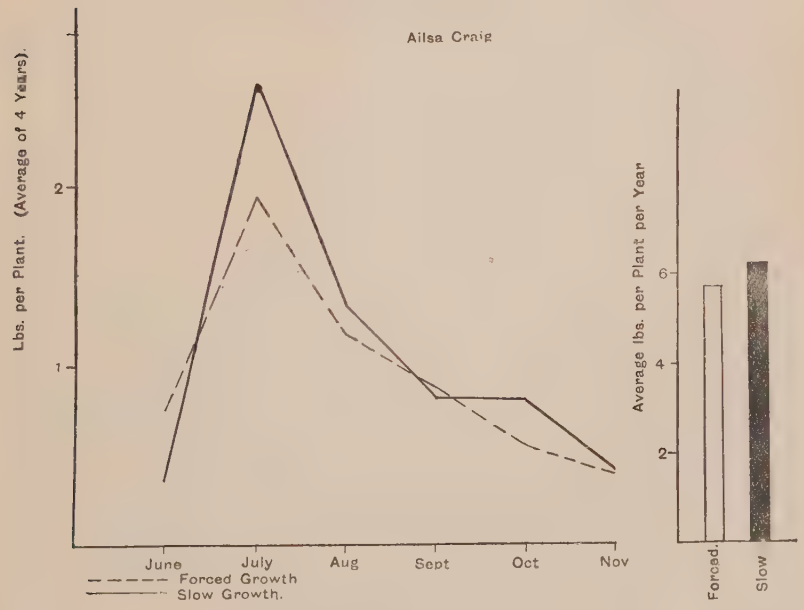
The experiment was performed on a larger scale in Houses 1 and 2 in the fourth year, forced growth being conducted in House 1, which is completely enclosed, and slow growth in the adjacent house. As nearly as possible the same amount of artificial heat and the same manurial treatment was applied in the two series, but no ventilation was given in the forced section until the air temperature reached 90°F. (accompanied by slight overhead damping between 10 and 11 a.m. when the temperature was rising to about 80°F.) while in the slow section ventilation was given when the air temperature reached 70°F., and no overhead dampings were given at any time.

The results of the four years are set out in graphical and diagramatic form below (Figs. 5—8). The graphs show the

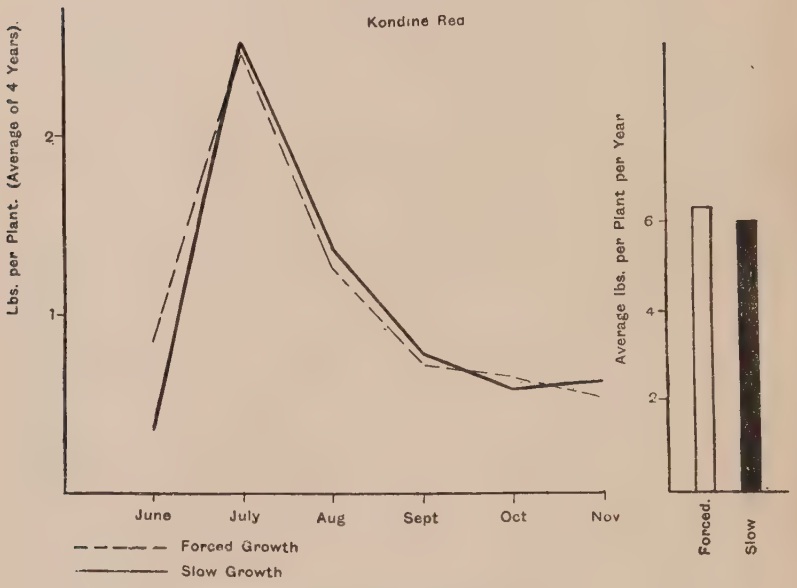
Forced *versus* Slow Growth. **Fig. 5.**



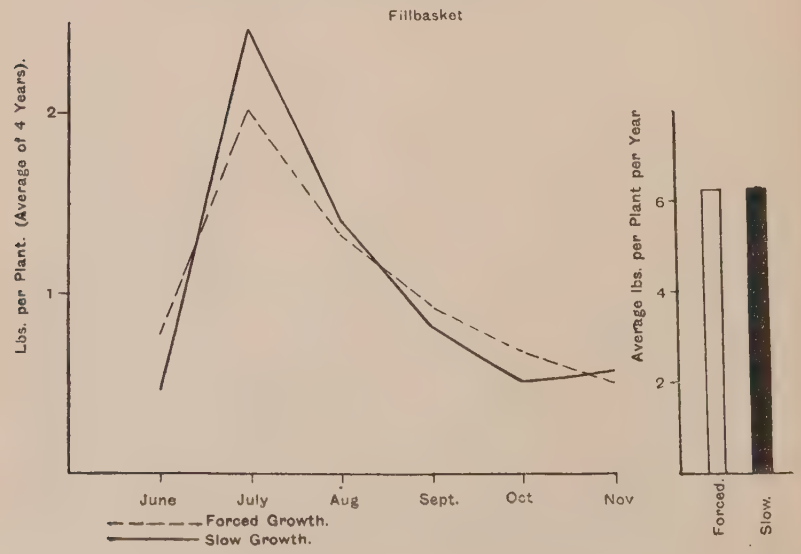
Forced *versus* Slow Growth. **Fig. 6.**



Forced *versus* Slow Growth. **Fig. 7.**



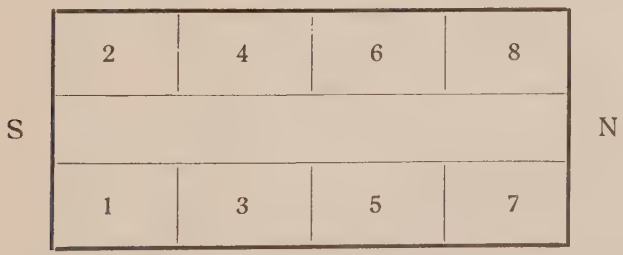
Forced *versus* Slow Growth. **Fig. 8.**



average yield for each month in pounds per plant; the continuous line representing the yield from the slow section, and the dotted that from the forced. In the diagrams the black column represents the average yearly yield in pounds per plant obtained as the result of slow growth and the white one that obtained by forced growth. Each variety is treated separately. The most striking result is the uniformly increased yield in June and decreased yield in July as the result of forcing. It is possible, therefore, by conserving the sun-heat to force the tomato crop and obtain an increased yield in June, thus relieving the market of the unusually heavy supply of tomatoes in July and at the same time take advantage of the increase in price proportional to the degree of earliness. The effect of forced growth upon the average total yield varies with the variety grown. Ailsa Craig shows a slight reduction, Kondine Red and Comet a slight increase and Fillbasket no difference in yield as the result of forcing.

Manurial Experiments.

In 1916, Houses 3 and 4 were set apart for manurial experiments with tomatoes. Each house was divided into eight equal plots of 32 square yards and on each plot 120 plants were grown. The position of the plots in each house are shown in the following diagram.



The treatment during the previous season had been uniform and consisted of giving lime to each house at the rate of sixteen tons to the acre; straw manure at the rate of forty tons to the acre; and bone meal at the rate of two and a half tons to the acre; the subsequent treatment as regards mulching, top dressing, watering, etc., being also uniform. In 1916 the following plot treatments were begun :—

Plot 1.—Standard manurial treatment consisting of 2 lbs. lime, 14 lbs. straw manure, ½ lb. bone meal, ½ lb. bone flour, ½ lb. ground hoofs, and ½ lb. sulphate of potash per square yard.

Plot 2.—Half the quantities of Plot 1.

Plot 3.—Double the quantities of Plot 1.

Plot 4.—*Complete artificials, lime, basic slag, superphosphate, sulphate of ammonia, nitrate of soda and sulphate of potash, equivalent in nutritive value to the materials given in Plot 2, plus 7 lbs. straw manure per square yard.

Plot 5.—* Complete artificials equivalent to Plot 2, but no straw manure.

Plot 7.—* Complete artificials equivalent to Plot 2, but omitting nitrogen.

Plot 8.—* Complete artificials equivalent to Plot 2, but omitting potash.

* The quantities given in Plots 4 to 8 were as follows :—

Plot 4.—*Before planting.* 1 lb. lime, 7 lbs. straw manure, 0.4 lb. basic slag, and 0.1 lb. sulphate of potash per square yard.

After planting in four equal instalments. 0.2 lb. sulphate of ammonia, 0.2 lb. nitrate of soda, 0.5 lb. superphosphate, and 0.2 sulphate of potash per square yard.

Plot 5.—Same as Plot 4 with the omission of straw manure.

Plot 6.—Same as Plot 4 omitting straw manure, basic slag and superphosphate.

Plot 7.—Same as Plot 4 omitting straw manure, nitrate of soda and ammonium sulphate.

Plot 8.—Same as Plot 4 omitting straw manure and sulphate of potash.

No mulching or top dressing other than the above was given.

During the first year of the experiment, the variety Comet was grown in both houses, but, from 1917 onwards, Comet was grown in House 3 and Kondine Red in House 4. In 1919 a change was made in the treatments of Plots 1, 2 and 3. Plot 1 became a double complete artificial plot (*i.e.* double Plot 5), Plot 2 became an unmanured control plot, and Plot 3 was given a standard dressing in the winter and top dressed with complete artificials during the summer. Owing to this change no reliable conclusions can be drawn from Plots 1 to 3 and the main interest centres round Plots 4 to 8, which have been submitted to the same treatment for five years. In the accompanying diagrams the yearly yields of Comet and Kondine Red on Plots 4 to 8 are illustrated (Figs. 9 and 10). The yields for

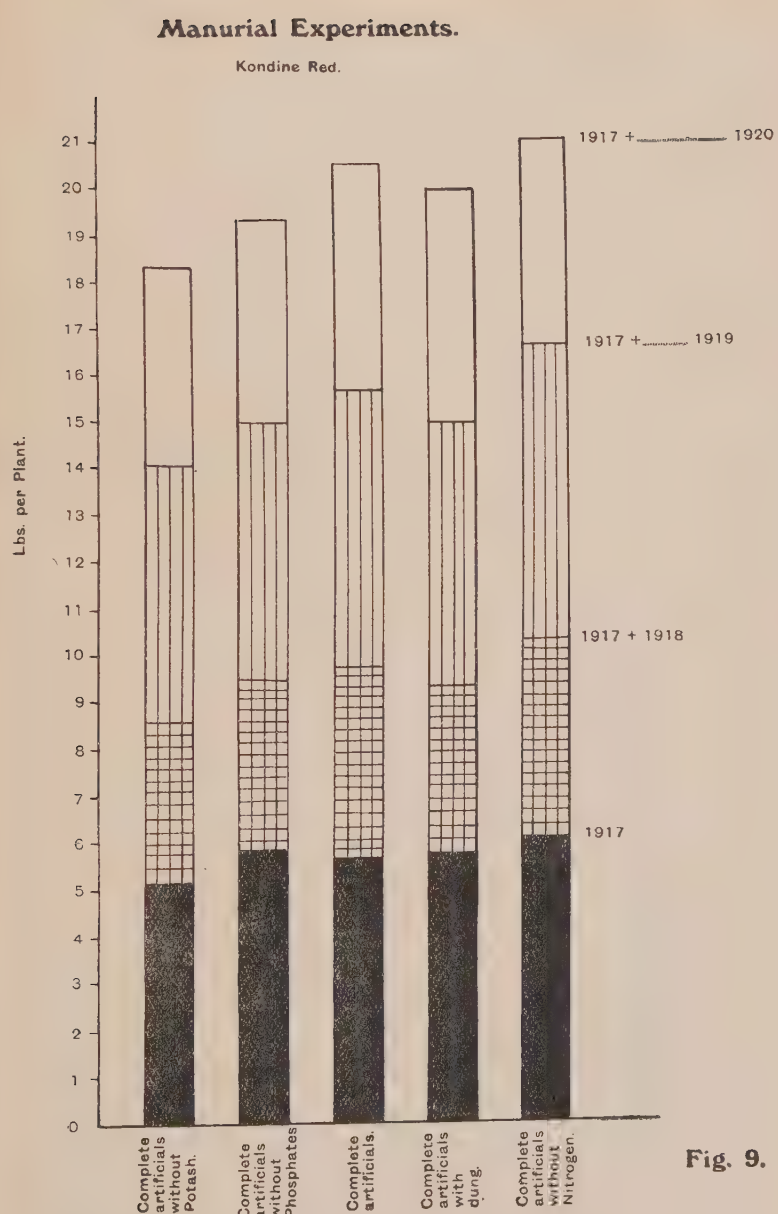

Manurial Experiments.
Kondine Red.
Lbs. per Plant.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
1917 + 1920
1917 + 1919
1917 + 1918
1917
Complete artificials without Potash.
Complete artificials without Phosphates
Complete artificials.
Complete artificials with dung.
Complete artificials without Nitrogen.

Fig. 9.

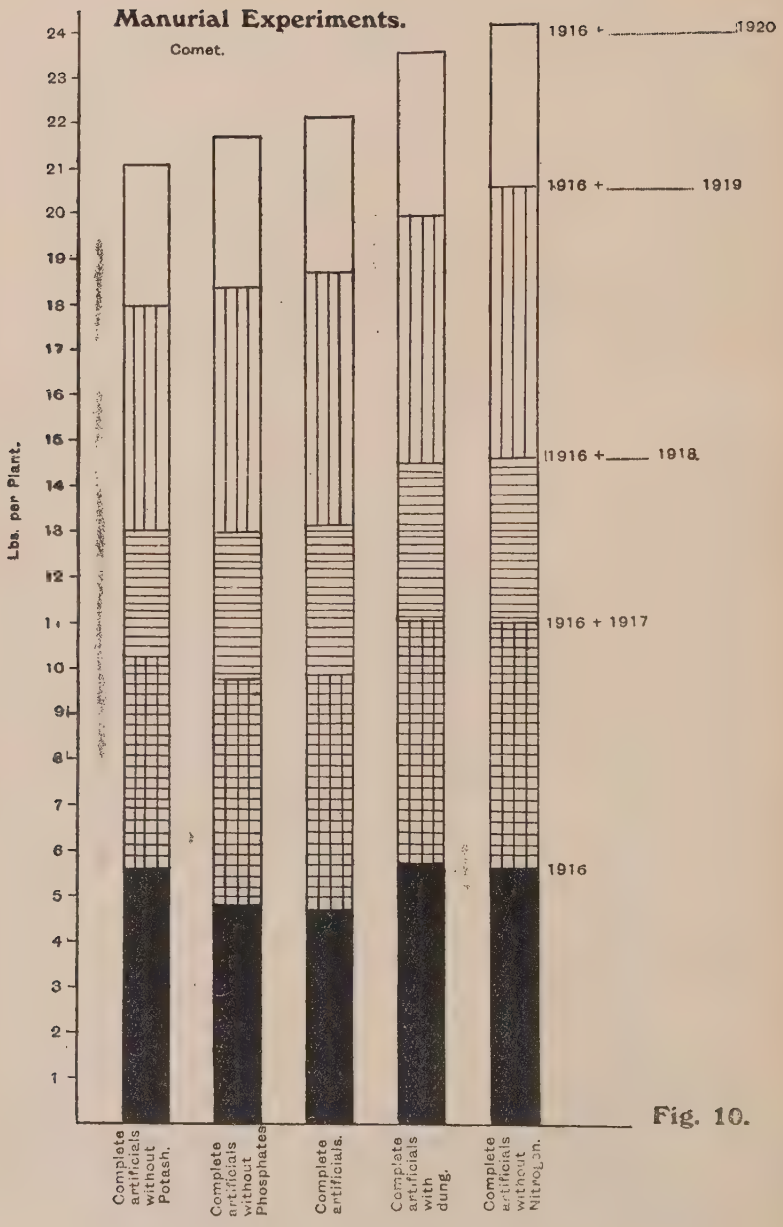

Manurial Experiments.
Comet.
Lbs. per Plant.
1916 + 1920
1916 + 1919
1916 + 1918
1916 + 1917
1916
Complete artificials without Potash.
Complete artificials without Phosphates
Complete artificials.
Complete artificials with dung.
Complete artificials without Nitrogen.

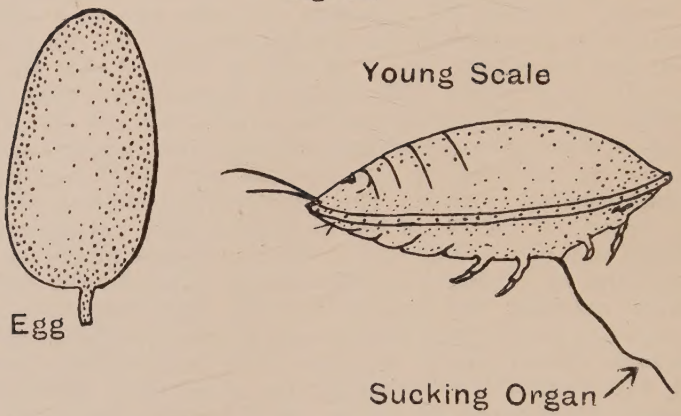
Fig. 10.

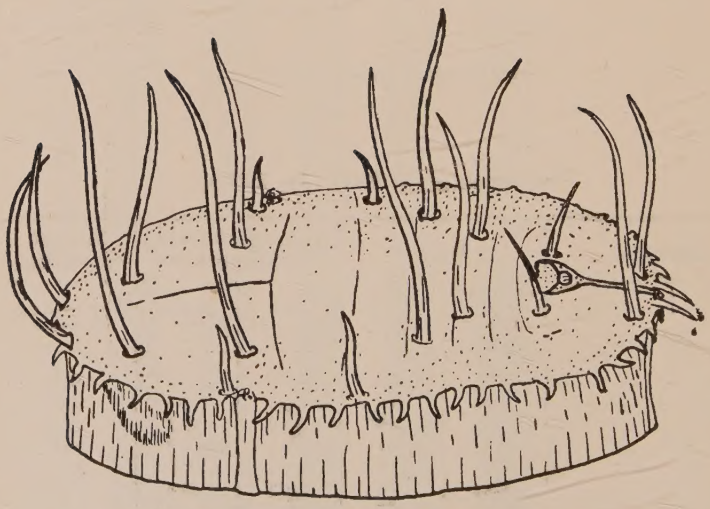
each consecutive year are placed one upon the other so that the highest point of the column shows the accumulated effect of each treatment upon Comet (5 years) and Kondine Red (4 years). Taking the complete artificial plot as a suitable standard for comparison the relative effects of the other treatments can be readily seen. It will be noticed that the two varieties show slight differences in behaviour. With both varieties the omission of potash greatly reduces the yield: omission of phosphates also causes a reduction though a smaller one, but the omission of nitrogen has until 1920 produced a distinct increase in crop. The effect of the addition of dung has varied; it increased the yield of Comet but apparently reduced that of Kondine Red. The importance of potash and phosphates as fertilisers for the tomato, especially the former, is most marked; the results from the plots that were given no nitrogen are of great interest and require careful attention. The main conclusions to be drawn from these experiments are that the tomato crop, when grown in borders, responds to generous treatment with potash; it also needs phosphates but it does not require much nitrogen and may indeed suffer if too much is added. In pots it is possible that the need for nitrogen is more marked.

Meteorological Records, 1920.

Month.	Rain.		Average outside Temperatures.		Bright Sunshine.
	Total fall. 5 inch Funnel Gauge.	No. of Rainy Days.	Day Maxm. °F.	Night Minm. °F.	Daily average in hours.
	Inches.				
January	2.63	18	46.9	35.8	1.40
February	0.49	10	49.0	35.7	2.34
March	1.49	16	53.9	37.5	4.20
April	3.77	21	58.4	42.1	2.90
May	1.35	13	63.6	46.6	7.50
June	1.54	10	67.6	50.4	7.40
July	4.43	17	66.0	51.8	4.74
August	1.52	8	65.1	49.6	5.00
September	2.61	13	64.5	49.4	3.60
October...	1.43	10	59.4	43.4	4.51
November	1.27	10	49.4	36.2	2.13
December	2.39	24	43.8	42.8	0.90
Total or Mean... ...	24.92	170	56.9	43.4	3.89

Fig. 14.





Mature Scale (Pupa).

Young Stages of the Greenhouse White Fly.